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Transit Priority Traffic Control Systems:

European Experience

October 1994

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cuta actu

Canadian Urban Transit Association
Association canadienne du transport urbain

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Prepared by:

M.M. Dillon Limited

CUTA Mission Statement

CUTA is the association of providers of urban transit services, suppliers and related organizations in Canada. Its mission is to promote the role of urban transit in enhancing mobility, and to support its members in the fulfilment of their mandate.

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The contents of this report reflect the views of the author(s) based on their research, but do not necessarily reflect the official views or opinions of the Canadian Urban Transit Association, nor of the organizations funding the Strategic Transit Research Program.

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Abstract

Congestion is a growing concern of transit managers, and affects transit in two different ways. First, it decreases the attractiveness of transit as a mode of travel since it increases travel times and, more importantly, reduces service reliability. Second, congestion increases the cost of providing transit service since more operators and vehicles are required for a given level of service. Various measures and/or computerized systems have been developed and put in place by cities that have wanted to increase the efficiency of transit by providing it with increased priority on urban roads. Such measures and computerized systems are more commonly found in Europe, and Canada lags in this respect. The Canadian Urban Transit Association (CUTA) therefore decided to conduct a study of ***Transit Priority Traffic Control Systems***, with special emphasis on the ***European experience*** with these systems. This report summarizes the results of this study.

The study was carried out through three tasks: 1) literature searches and survey of European Cities; 2) detailed case studies in five European cities (i.e. London, Stuttgart, Zurich, Nancy, and Angoulême); and 3) analysis of the issues related to the implementation of Transit Priority Traffic Control Systems in the Canadian context. The study shows that the technology is clearly technically feasible in the Canadian context, but identifies a number of institutional issues that will need to be addressed.

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Résumé

L'encombrement de la circulation urbaine est un problème croissant pour les directeurs de réseaux de transport en commun, et crée deux sortes de problèmes pour le transport en commun. D'abord, cela augmente les temps de parcours et réduit la fiabilité du service, et ainsi décroît l'attrait du transport en commun comme mode de transport pour la clientèle potentielle. En même temps, cela augmente les coûts du service parce que cela exige plus de chauffeurs et de véhicules pour un niveau de service donné. De différents mesures et systèmes informatiques ont été développés et mis en service par les villes qui désiraient augmenter l'efficacité du transport en commun en lui donnant une priorité accrue dans la circulation urbaine. Ses mesures et systèmes se retrouvent beaucoup plus souvent en Europe, et le Canada est en retard par comparaison. C'est pourquoi l'association canadienne du transport urbain a entrepris une étude sur ***les systèmes de priorité au transport en commun aux feux de circulation***, avec l'accent mis en particulier sur ***l'expérience européenne***. Ce rapport présente les résultats de cette étude.

L'étude comprenait trois éléments: 1) des recherches de la littérature et une enquête auprès de réseaux européens; 2) des études de cas détaillées dans cinq villes européennes (Londres, Stuttgart, Zurich, Nancy, et Angoulême); et 3) une analyse des questions concernant l'implantation de cette technologie dans le contexte canadien. L'étude a clairement montré qu'il n'y a pas de limitations techniques pour la mise en place de cette technologie dans le contexte canadien, mais a soulevé plusieurs questions au niveau institutionnel / organisationnel méritant plus de réflexion.

Mots-clés	Langue
transport en commun; mesures de priorité; systèmes de contrôle de la circulation urbaine; pré-emption des feux; systèmes d'aide à l'exploitation	Anglais Ce rapport sera aussi disponible en français. (rapport PRSTC 9-1)
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TRANSIT PRIORITY TRAFFIC CONTROL SYSTEMS
EUROPEAN EXPERIENCE

1. INTRODUCTION TO STUDY

Transit has the potential of serving the fundamental mobility needs of a city in a highly efficient manner with minimal social costs. However, the extent to which this is realized will greatly depend on the degree to which transit is integrated into the structure and life of the urban area, and in particular the degree of coordination in the planning and management of land-use, urban roads, and transit. Policies concerning land-use, road investments, and road use (traffic signal timing, parking restrictions, etc.) will shape both long-term patterns of travel and the conditions under which the different modes compete. Such policies will have a profound effect on the potential demand for transit and its cost (through the impact of travel distances and speeds).

One area that is of particular concern for transit systems relates to the degree of priority for transit on urban roads, and in particular in relation to traffic signal systems. Transit's ability to efficiently serve the needs of the community will be influenced considerably by the day-to-day operating conditions transit vehicles face on urban roads, and therefore by the policies that govern the use of these roads. For example, congestion affects transit in two different ways. First, it decreases the attractiveness of transit as a mode of travel since it increases travel times and, more importantly, reduces service reliability. Second, congestion increases the cost of providing transit service since more drivers and vehicles are required for a given level of service. Various measures and/or electronic systems have been developed and put in place by cities that have wanted to increase the efficiency of transit by providing it with increased priority on urban roads. Such measures and systems are more commonly found in Europe, and Canada lags in this respect, which is all the more surprising given the strong support for transit found in Canadian cities.

Given the above, the Canadian Urban Transit Association decided to undertake a study of transit priority traffic control systems. This report summarizes the results of that study.

The study was carried out through three tasks: 1) Task 1 - Literature Search and Survey of European Cities; 2) Task 2 - Field Study of Selected Cities; and 3) Task 3 - Implementation of Transit Priority Traffic Control in Canadian Cities

Chapter 2 discusses the results of the Literature Searches and the Survey of European Cities. Chapters 3-9 present the findings from the five European case studies, and Chapter 10 explores various issues related to the implementation of this technology in the Canadian context.

2. LITERATURE SEARCH AND SURVEY OF EUROPEAN CITIES

2.1 INTRODUCTION

The objective of Task I was to undertake a survey of literature related to transit priority in general, and to traffic control-related systems in particular.

The suggested specific activities to be conducted under Task I were as follows;

a) Survey standard databases (e.g. TRIS, NTIS) and other potential sources (ITE, TAC) to identify all literature pertaining to transit priority in general, and transit priority traffic control systems in particular.

b) Classify the references identified by theme or topic area, and prepare a comprehensive bibliography;

c) Obtain (as possible) and review those references specifically related to transit priority traffic control systems.

d) Summarize findings from the review of literature, including the preparation of a list of cities where transit priority traffic control systems have been implemented and which will help in the selection of case study sites for Task 2.

In this regard, the assembly of data for Task I was broken into two general geographic areas:

- North America
- Europe

A summary of the approach and findings follows below.

2.2 NORTH AMERICAN SITUATION

Data Sources

Major Data Bases

A literature search of the two major North American data bases:

a) Transportation Research Information Service (TRIS);

b) National Transportation Information Service (NTIS);

resulted in a long list of reports and articles on transit priority measures dating back to the early 1970's when the strategy became popular.

Following a review of the literature search, emphasis was placed on identifying key reports relating to the application of traffic signal priority for transit vehicles. Emphasis was placed on a review of cities where the strategy was currently being used for bus operation. From this search, nine reports (Table 1) were identified as having some potential. On further investigation it was found that either the research was theoretical in nature, the project had not proceeded to full operation, or the project had been terminated.

TABLE 1

LITERATURE SEARCH - NORTH AMERICA
BUS PRIORITY AT TRAFFIC SIGNALS

1. Bus Traffic Signal Pre-emption and AVL Study. Johnson, M.H., Chicago Transit Authority, 1988. Chicago Illinois.

2. Transit Signal Priority, Another Look. Bishop, C.M., M.M. Dillon Ltd., Toronto, Canada. ITE Compendium, 1990. pp381-391.

3. Bus Actuated Traffic Signals. Salvador, J.M., Ministry of Transport, Quebec. 1989.

4. The Evaluation of Passive Bus Detectors in Minneapolis. Belrose, W., Hildebrand, D. City of Minneapolis Traffic Operations Division, Minneapolis, Minnesota, U.S.A. January 1989.

5. Operational Evaluation of Bus Priority Strategies. Pouphail, N.M. Illinois University, Chicago. Transportation Research Board. N994, 1994. pp30-34.

6. Evaluation of Control Strategies for Bus Pre-emption of Traffic Signals. Smith, M.J. New Jersey Department of Transportation. March 1985.

7. Bus Priority Signal Control Evaluation. Nogress, R.O., McCasland, W.R. North Dakota State University; Texas Transportation Institute. ITE Compendium, 1982. pp284-295.

8. City of Concord. Evaluation of Bus Priority Signal System. DKM Transportation Consultants. 710 South Broadway, Suite 302, Walnut Creek, California. July 1978.

9. Urban Traffic Control and Bus Priority System. Sperry Rand Corporation. Sperry Systems Management Division. Great Neck, New York. (Various Reports 1972-1976).

Secondary Sources

Further discussions with the Canadian Urban Transit Association (CUTA), the Toronto Transit Commission (TTC), the American Public Transit Association (APTA), the Institute of Transportation Engineers (ITE), and staff from the cities of Chicago and Minneapolis resulted in the following conclusions:

- Many cities have tried signal priority for transit vehicles and have discontinued the operation for one reason or another.

- The Cities of Toronto and Chicago are investigating strategies and technology for future implementation of signal priority.

- The City of Edmonton has been using a variety of transit priority strategies at signalized intersections for some time.

- The Cities of Charlotte, North Carolina and Bremerton, Washington are currently using the 3M Opticom system for providing signal priority for buses.

A discussion of the current status of signal priority for transit in these cities follows below:

<u>Toronto</u>

The Toronto Transit Commission (TTC), in association with the Metropolitan Toronto traffic authorities, has undertaken a phased study of signal priority for transit vehicles. The initial phases on a streetcar line have indicated that significant benefits are possible which would offset the cost of implementation. The most recent phase of the study involved a review of various technologies for bus detection and signal actuation. The intent was to determine which technology was best suited for the Toronto situation. A major implementation of traffic signal priority for streetcars is now being implemented and the next phase will be a pilot test of traffic priority on one bus route. A list of technology suppliers identified by TTC is included in Appendix A-1.

The TTC provided a summary of discussions they had with several authorities in North America including representatives from the following cities:

- Canada
  - Edmonton, Alberta
  - Vancouver, British Columbia
  - Ottawa, Ontario

- United States
  - Minneapolis, Minnesota
  - Louisville, Kentucky
  - Dallas, Texas
  - Santa Clara, California
  - Los Angeles, California
  - San Francisco, California
  - Chicago, Illinois
  - Memphis, Tennessee

Table 2 (from the TTC) provides the list of cities canvassed regarding bus pre-emption applications and technology used. It would appear that the use of signal priority for transit has not so far met with great success for many cities in North America.

Chicago

It appears that Chicago is another front-runner in developing a system to provide signal priority for transit vehicles (buses). Chicago officials, on determining that there was a concentration of systems in Europe which were using the functions most sought by the CTA, undertook a field study in October 1991. Transit priority at signalized intersections was observed in:

- Zurich, Switzerland : light rail and buses;
- Amsterdam, Netherlands : light rail and buses;
- Osnabrück, Germany : buses;
- Stuttgart, Germany : light rail;
- Hanover, Germany : light rail and buses;
- Wiesbaden, Germany : buses;
- Saarbrücken, Germany : buses.

Documents from the field trip were collected in a document, entitled:

Automatic Vehicle Location/Control and Traffic Signal Preemption - Lessons from Europe, Chicago Transit Authority, September 1992

TABLE 2

BUS PREEMPTION APPLICATIONS

Location	Year Documented	Mode	Priority Methods	Actuation Technology	No. of Signals	Traffic Control Strategy	Evaluation Results	Current Status
Leicester, England	1972	bus	truncation, compensation, inhibition	passive transponder	1	isolated	average bus delay reduced by 10 seconds	unknown
Louisville, Kentucky	1972	express bus	extension, truncation	optical detector	8	isolated	15% to 19% reduction in PM travel time	discontinued
Woking, England	1976	bus	truncation, phase skipping	loop detector in bus-only lane	1	isolated	average bus delay reduced by 7 seconds	unknown
Miami, Florida	1977	express bus	N/A	N/A	37	various	23% reduction in travel time	discontinued
Concord, California	1978	bus	extension, truncation	optical detectors	12	isolated and fixed time	10% reduction in bus travel time	discontinued
Melbourne, Australia	1978	bus	extension, truncation, compensation, inhibition	passive transponder	1	isolated	significant reductions in bus delays	unknown
Santa Clara, California	1978	bus	N/A	optical emitters	60	N/A	system worked well but abuse and high maintenance costs degraded benefits	discontinued
Dallas, Texas	1982	bus	extension, truncation, phase skipping inhibition	active transponder	N/A	isolated	5% reductions in bus travel time, peak direction	discontinued
Memphis, Tennessee	1982	express bus	extension, truncation, phase skipping	optical detectors	24	isolated	47% to 72% reduction in PM express bus signal delay	discontinued

Location	Year Documented	Mode	Priority Methods	Actuation Technology	No. of Signals	Traffic Control Strategy	Evaluation Results	Current Status
S. Hertogenbosch, Netherlands	1982	bus	N/A	passive transponder	28	N/A	10% reduction in bus travel time	unknown
Los Angeles, California	1986	bus	extension, truncation	optical emitters	49	various	4.2% travel time reduction	operational[1]
Minneapolis, Minnesota	1989	local bus	extension, truncation, phase skipping	signature recognition	20	fixed time	signature recognition reliable but limited to one specific type of bus	operational[2]
Zurich, Switzerland	1989	bus	extension, truncation	active transponder	217	N/A	N/A	unknown
Ottawa, Ontario	N/A	bus	special phase	four microdots	3 or 4	N/A	N/A	operational

Notes: N/A - not available
1. System not operating pending software modifications
2. System not operating pending purchase of new computer hardware and software

SOURCE: TORONTO TRANSIT COMMISSION

Chicago now intends to undertake a pilot test and has issued an RFP for a bus service management system. They intend to co-ordinate their signal priority for transit vehicles through their AVLC system.

Edmonton

Signal Timings

The CBD signal coordination is designed to provide transit priority. This measure was first introduced in 1975 and continues to be the most effective overall transit priority measure. Coordinated signal plans for a sub-area of 70 signals are maintained using TRANSIT. Initial transit delay reductions of 15-20% were realized with this measure.

Priority Signalization

There are three types of priority signalization in use in Edmonton:

Queue Jump Signal

This strategy provides buses with a headstart on regular traffic. This type of signal priority has been used since 1973. Initially, transit operators used a simple garage door opener to send a signal activation request. Later, the issuance of this type of signal was only permitted in locations where a bus would be present during each signal cycle. The issuance of the transit display is achieved through the timing plan structure. There are currently 4 such application locations in Edmonton.

Timing Plan Modification

The modification of signal plans to provide prioritized green allocation for transit is used at signal locations adjacent to the northeast LRT line. Because the presence of trains is easily detected in advance of arrival at an intersection, the timing plans are modified to ensure minimal impact to the LRT operation. This has required a linkage of the LRT and traffic control system. This type of priority has been in place since 1978.

Localized Transit Priority

Since 1972, the City of Edmonton has operated half signals (the main street is fitted with conventional red-amber-green displays which normally display green. The side street is controlled by stop signs. When a pedestrian activates the signal, an amber display, followed

by red, is displayed on the main street). This type of control device was developed to permit safe pedestrian crossing without inducing traffic shortcutting. In 1978, the City of Edmonton developed an inductive loop detection system that could differentiate between trucks, cars and transit vehicles. Several half signals were fitted with these loops in order to facilitate transit access to the arterial system. Of the 250 half signals in operation, 80 provide transit priority.

Charlotte, North Carolina

Signal priority for transit in Charlotte appears to be a resounding success, yet a well kept secret from the transit industry. Charlotte has been providing priority for express buses at 11 intersections over a four-mile stretch of Central Avenue since the mid 1980's. The success of the system has been measured by the following results.

- bus delay at signals in the area of priority has been reduced from six minutes to two minutes (67%);
- ridership has increased. Ten buses are now used compared to four when the system was initiated;
- the route has been extended at no extra cost;
- due to reduced auto stop time along the route it is believed that air pollution has been reduced and gasoline consumption reduced;
- the 3M Opticom technology has worked effectively with minimal problems;
- following initial reaction, complaints from motorists have disappeared.

Bremerton, Washington

Kitsap Transit, in Bremerton, is in the process of evaluating the 3M Opticom system for the provision of signal priority for transit vehicles. A current state law limits the provision of such a priority system to emergency vehicles only. For this reason Bremerton is doing a full scale evaluation of the costs and benefits.

The evaluation, currently underway, is being completed by the University of Washington. The system will include 42 intersections equipped with the 3M Opticom system serving 25 to 30 bus routes. Experience to date has been very positive and complaints were minimal.

Bremerton has a general policy of far side stops and mentioned this fact as a positive in their strategy.

Summary of North America

While there have been past demonstration projects providing priority to transit vehicles at signalized intersections, with the exception of Charlotte, North Carolina, (which provides priority for express buses only) it appears that there has been little support for continuation of the systems. Recently, there has been renewed interest by a few transit systems to increase the attractiveness and efficiency of their systems through improvements in travel time. Bremerton, Washington has followed the Charlotte example and is using the 3M Opticom equipment for their system. For the larger properties the current emphasis appears to be on the appropriate technology for their environment and the most cost effective method of installation.

Chicago and Toronto, the apparent leaders in the field, have installed or are installing AVLC systems. Toronto, with an AVLC system up and running is taking a separate approach for traffic signal priority (TSP). Chicago, on the other hand, is currently developing an AVLC system and hopes to incorporate TSP with it. Toronto is expanding its priority system on the Queen Street line and also intends to implement priority on a suburban bus line. However, this test will not be complete for some time.

2.3 EUROPEAN SITUATION

2.3.1 Data Sources

The following activities were carried out in order to identify the most promising European case study sites:

- draw up a list of European cities known to be using transit signal priority strategies along with contact names and addresses;
- undertake a literature search of the Transportation Research Laboratory (TRL) database; and
- design an initial questionnaire to gather basic information about the priority schemes;

The following is a summary of the foregoing tasks.

2.3.2 Selection of European Cities

There is, relative to other parts of the world, widespread use of transit priority schemes, and especially signal priorities, in Europe. In selecting cities for investigation, an important criteria was to maximize the opportunities to document the effectiveness of the priority measures implemented, especially signal priority measures. It was also important to investigate the experience of cities in a number of countries in order to obtain a wide range of technical approaches with respect to traffic signal systems in priority measures implemented. Such an approach enhanced the task of short listing cities to provide diversity in the application of transit signal priority measures, and in meeting the study's objectives.

Using a number of sources, including CUTA, TPA's current and past experience and contacts in Europe, transit reference manuals, and transport journals, the following 24 towns/cities were chosen for the survey:

•	Denmark	: Arhus
•	France	: Angoulême, Caen, Lille, Nancy, Nice
•	Germany	: Darmstadt, Hannover, Karlsruhe, Stuttgart, Osnabrück, Saarbrücken, Weisbaden
•	Italy	: Turin
•	Netherlands	: Amsterdam, Rotterdam, Schiedam
•	Sweden	: Gothenburg
•	Switzerland	: Zurich
•	United Kingdom	: Cardiff, London, Manchester, Oxford, Southampton

2.3.3 TRL Literature Search

A literature search of the UK Transport Research Laboratory (TRL) was also undertaken.

The search of the TRL database in fact produced very little that is with the exception of two possible useful reports, both in the London area.

1. Bus Selective Detection in Swansea. Collier, S.C., Department of Transport. London, England. 1980.

2. The Scope for Bus Priorities in London. London Boroughs Association Review. Hurdle, D., October 1990.

These reports were obtained for review and a summary write up is included in Appendix A-2. London and Swansea were two of the cities on the survey list.

2.3.4 Design of Questionnaire

The purpose of using a questionnaire was to provide a means by which enough information could be collected from the 24 European towns and cities identified to allow the study team to select a number of cities for more detailed investigation.

The questionnaire was designed to efficiently obtain information on:

- other priority measures, in addition to priority at signalized intersections, which form part of the total package of co-ordinated measures of the scheme(s);
- the type of traffic signal system in place;
- the link between signal system and other facilities, such as passenger information system; and
- the type of vehicle/signal interface and control.
- the type of "before" and "after" studies undertaken, if any, as well as the availability of the results.

A copy of the questionnaire and the accompanying letter sent to the cities, is included in Appendix A-3.

2.3.5 Summary of Questionnaire Response

Questionnaires were sent to a total of 24 European cities, 20 in December 1992, and four more later in January 1993. Twenty responses were received. The remainder of the cities were called but no responses were forthcoming.

The 20 cities responding have indicated 21 priority schemes for transit at signalized intersections. Turin, Italy has implemented two different schemes.

The following subsections discuss the results of the analysis under the various subheadings of the questionnaire.

Priority Measures

By far the most common measure to support transit priority at signalized intersections includes the use of reserved lanes for transit vehicles, which has been adopted in 17 cases. This is followed by 'transit-only turning movements' (10 cases), 'transit-only streets' (eight cases), and 'exclusive right-of-way' (six cases).

Not surprisingly, the transit mode most favoured for priority at signalized intersections, in 18 out of the 21 schemes, is the bus which is also the most common form of public transport in Europe. There are also schemes giving priority to trams (nine cases), light rail transit (LRT) (seven cases), and trolley buses (two cases).

Traffic Signal System

The traffic signal system giving priority to public transport, in the maximum number of cases (12), is the isolated signal. (See Appendix A-4 for definition of traffic signal systems.) Priority within fixed-time and on-line Urban Traffic Control (UTC) systems were reported in five cases and six cases respectively. 'Other' systems were reported in three cases, namely 'Green-Wave' to main road traffic in Darmstadt and Hannover in Germany, and a custom-built computerized, but decentralized, traffic signal system in Zurich.

Five cities operate more than one type of signal system.

The size of schemes, based on the number of signalized intersections providing priority to public transport, range between five (Osnabruck, Germany) and 330 (London, UK). A breakdown of the schemes, based on number of intersections, is given below:

Number of Signalized Intersections Giving Priority	Number of Schemes
1 - 20	8
21 - 50	4
51 - 100	3
101 - 200	4
>200	2
	21

Four cities have implemented active passenger information systems which are linked to their signal priority system. In France, Angoulème provides passenger information on board buses, at bus stops, and via videotext (Minitel), whilst Nice provides information at bus stops only (VideoBus system). Turin, Italy is the third city to indicate a connection to the priority system, but its passenger information system is currently switched off. Finally, Hannover, in Germany, provides up-to-date passenger information at bus stops and stations on visual display units.

Vehicle/Signal Interface

Excluding the use of inductive loops in reserved lanes (11 cases), vehicle detection on a shared traffic lane is most often achieved by the combination of inductive loops and on-board vehicle transponders (10 cases). There are a significant number of schemes (7) which identify transit vehicles, namely buses and trolley buses, by their profiles. These are obtained by analyzing the shape of the signal that occurs when a vehicle traverses over a loop detecting unit.

There are also examples of radio (five), microwave (two), and infra-red (two) technologies for communication, directly or indirectly, with signal controllers.

By far, priority is achieved by direct communication between transit vehicles and a local intersection signal controller (18 cases). However, there are six reported cases of communication via a central signal control centre to a local signal controller. It should be noted that 4 systems have both types of communication.

Impact of Priority at Signalized Intersections

The impact of signal priority measures has been assessed for 15 schemes, though the results of only 11 are reported to be available.

From the brief description given in the completed questionnaires and accompanying documents, it is not feasible to report on the results of effectiveness in a meaningful way due to the varied circumstances in which the studies have been conducted. It can, however, be reported that all who provided information (seven cases) claim some degree of success. It is interesting to note the various measures of effectiveness quoted:

- time lost due to signals;
- transit waiting times during red phase;
- transit waiting times at intersections;
- journey times;
- standard deviation (variability);
- number of stops at intersections;
- transit throughput during green phase; and
- patronage level.

2.3.6 Summary and Discussion

A summary of the response to the questionnaire follows:

- an overall response rate of 83% (20 cities) was achieved;
- priority at signalized intersections is generally supported by other transit priority measures, most notably reserved lanes, transit-only streets, and transit-only turning movements;
- the bus is the most common transit mode involved in priority schemes at signalized intersections. There are, however, a number of schemes giving priority to trams and to light rail transit;
- the signal system giving priority in the maximum number of cases is the vehicle-actuated isolated signal, with few cases involving fixed-time or on-line UTC systems;
- the communication link is, in most cases, between transit vehicles and a local intersection signal controller. There are also a number of schemes where communication is via a central control centre;
- automatic vehicle location is achieved by a variety of technologies and techniques including, in decreasing order of frequency:
  - on-street inductive loop detectors combined with on-board vehicle transponders,
  - on-street inductive loop detectors outputting vehicle profiles,
  - radio communication, and
  - microwave, and infra-red beacons;
- some assessment of the effectiveness of signal priority at intersections has been undertaken in most cases, and all those who provided information claim some degree of success; and

- there is a wide range of measures used to report the effectiveness of signal transit priority schemes.

Table 3 presents the summary of the analysis undertaken, and is accompanied by the questionnaire illustrating the coding used.

It is clear that the level of detail of the analysis undertaken, and of the results reported, reflects the level of detail of the questionnaire. However, the aim of the questionnaire was to provide some basic information about transit priority schemes at signalized intersections to enable shortlisting for any further investigation and, ultimately, for possible site visits.

SURVEY OF EUROPEAN TRANSIT SYSTEMS - SUMMARY
(See Appendix A-3 for Actual Survey Form)

OTHER PRIORITY MEASURES ASSOCIATED WITH SIGNAL PRIORITY SYSTEM:
111 Reserved Lanes / Tracks
112 Public transport only Streets
113 Exclusive Right-of-Way
114 Public Transport only Turning Movements

WHICH MODE RECEIVES PRIORITY AT INTERSECTION:
121 Bus
122 Trolley Bus
123 Tram
124 LRT
125 Metro

TRAFFIC SIGNAL SYSTEM:
131 Isolated Signal
132 Fixed Time Urban Traffic Control (UTC)
133 On-Line UTC System (e.g. SCOOT, SCATS, etc.)
134 Other
14 Number of Intersections That Provide Priority to Transit
15 Is Transit Priority Traffic Control System Linked to Other Systems

VEHICLE SIGNAL INTERFACE
161 Inductive Loops in Reserved Lanes
162 Inductive Loops (Vehicle Profile)
163 Inductive Loop and On-Board Vehicle Transponder
164 Microwave Beacon
165 Radio Link
166 Infra-Red Beacon

SIGNAL CONTROL
171 Local Junction Signal Controller
172 Central Signal Control centre
173 Other

EVALUATION STUDIES
18 Feasibility Study Undertaken?
19-21 Before and After Studies to Measure Vehicle Delay, and Availability?
22-23 Modelling of Impacts, and Availability?

TABLE 3

SUMMARY OF ANALYSIS OF RETURNED QUESTIONNAIRES

Town/ Country	Population	Other Priority Measures				Mode					Traffic Signal System						Vehicle Signal Interface						Signal Control			Evaluation Studies					
		111	112	113	114	121	122	123	124	125	131	132	133	134	14	15	161	162	163	164	165	166	171	172	173	18	19	20	21	22	23
Arhus DK	250,000	1	1	0	0	1	0	0	0	0	1	0	0	0	15	0	1	1	0	0	0	0	1	0	0	0	0	0	0	0	0
Angouleme F	100,000	1	1	1	1	1	0	0	0	0	1	0	0	0	40	1	0	0	0	0	1	0	1	0	0	1	1	0	1	0	0
Caen F	115,000	1	0	0	1	1	0	0	0	0					100	0															
Lille F																															
Nancy F	250,000	1	1	0	0	1	1	0	0	0	1	0	1	0	122	0	1	1	0	0	1	0	1	1	0	1	1	0	1	0	0
Nice F	400,000	1	0	0	1	1	0	0	0	0	1	0	1	0	17	1	0	0	0	1	0	0	1	1	0	1	0	0	0	0	0
Darmstadt D	140,000	1	0	0	0	1	0	1	0	0	0	1	0	1	34	0	0	0	0	1	0	0	1	0	0	1	1	1	1	0	0
Hannover D	500,000	1	0	0	1	1	0	0	1	0	0	0	0	1	120	1	1	0	1	0	0	0	1	0	0	0	1	1	1	0	0
Karlsruhe D	270,000	1	1	1	0	0	0	1	1	0	0	0	1	0	52	0	0	1	1	0	0	1	1	0	0	0	1	1	1	0	0
Osnebrück D	180,000	1	0	0	0	1	0	0	0	0	0	0	1	0	5	1	0	0	0	0	0	0	1	0	0	0	1	0	0	1	1
Saarbrücken D																	0	0	0	0	0	1	1	0	0	1	0	0	0	0	0
Stuttgart D	560,000	1	0	1	0	1	0	1	1	0	1	1	1	0	148	0	1	1	1	0	1	1	1	0	0	1	1	0	0	0	0
Weisbaden D	280,000	1	0	0	1	1	0	0	0	0	0	0	1	0	10	1	0	0	0	0	1	0	1	0	0	1	1	1	1	1	0
Turin I	1,000,000	0	1	0	1	1	0	1	0	0	1	0	0	0	43	1	1	1	0	0	0	0	1	1	0	0	1	1	1	0	1
		0	1	0	1	0	0	1	1	0	1	0	0	0	40	1	1	1	0	0	0	0	1	1	0	0	1	1	1	0	1
Amsterdam NL																															
Rotterdam NL	630,000	1	0	0	1	1	0	1	1	0	1	0	0	0	114	0	1	0	1	0	0	0	1	0	0	0	0	0	0	0	0
Schiedam NL	70,000	1	0	0	0	1	0	1	0	0	1	0	0	0	19	0	1	0	1	0	0	0	1	0	0	0	1	0	1	0	0
Gothenburg S	450,000	1	0	1	0	1	0	1	0	0	1	1	0	0	100	1	1	1	1	0	0	0	1	0	1	1	1	0	0	0	0
Zurich CH	375,000	1	1	1	1	1	1	1	1	0	0	0	0	1	280	0	1	0	1	0	0	0	0	1	0	1	1	1	1	0	0
London UK	6,000,000	1	0	0	0	1	0	0	0	0	1	0	0	0	330	0	0	0	1	0	0	0	1	0	0	1	1	0	1	0	0
Manchester UK	450,000	0	0	0	0	0	0	0	1	0	0	1	0	0	8	0	0	0	1	0	0	0	1	0	1	1	1	0	0	0	0
Oxford UK	120,000	0	0	0	0	1	0	0	0	0	1	0	0	0	6	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0
Southampton UK	200,000	1	1	1	1	1	0	0	0	0	0	1	0	0	13	0	1	0	0	0	0	0	0	1	0	1	1	0	1	0	0
Swansea UK																															
		17	6	6	10	16	2	9	7	0	12	5	6	3		8	11	7	10	2	4	3	18	6	2	12	15	6	11	2	3
		68%	38%	29%	48%	72%	10%	43%	33%	0%	60%	25%	30%	15%		38%	55%	35%	50%	10%	20%	15%	90%	30%	10%	60%	75%	30%	55%	10%	15%

2.4 SELECTION OF CITIES FOR FURTHER STUDY

The objective of selecting a subset of the cities which replied to the questionnaire was to obtain more detailed information about the technology, the techniques, the application, experience and effectiveness of transit priority at signalized intersections in Europe. It was hoped that the knowledge gained would be of assistance to the application of transit priority at signalized intersections in Canada.

2.4.1 Criteria for Selection

Four criteria were used for the selection of cities to be the subject of a more detailed study, namely:

1. some impact studies, on the effectiveness of transit priority at signalized intersections, have been undertaken;

2. priority for buses is in effect at a significant number of locations of their overall priority system;

3. a range of vehicle detection technologies is covered; and

4. small, medium and large schemes are included.

2.4.2 Cities Selected

Using the above criteria, five cities from four European countries were selected. These are Angoulème and Nancy (F), Stuttgart (D), Zurich (CH), and London (UK). Table 4 provides a summary of the characteristics of the cities selected. Details of the operations in these cities are included in the case study summaries in the following sections of the report.

TABLE 4

Cities Selected for Field Trips

	Population	Modes of Transit	AVL Technique	Number of Junctions Giving Priority	Communication Via	Effectiveness Studies?
Angoulème	100,000	B	R	40	LJSC	Yes
Nancy	250,000	B, TB	VP, R	122	CSCC	Yes
Stuttgart	560,000	B, T, LRT	VP, IL + VT, R, IR	148	LJSC	Yes
Zurich	375,000	B, TB, T, LRT	IL + VT	280	CSCC	Yes
London	6,700,000	B, M*	IL + VT	330	LJSC	Yes

LEGEND:

B, TB, T, LRT, M : Bus, Trolley Bus, Tram, Light Rail Transit, Metro* (underground)
VP, IL +VT, R, IR : Vehicle Profile, Inductive Loop and Vehicle Transponder, Radio, Infra-red
CSCC : Central Signal Control Centre
LSJC : Local Signal Junction Contrciler

2.4.3 Summary Description of Cities Recommended for Further Study

1. Angoulême, France

Background

Angoulême has a population of some 100,000 inhabitants. Its bus services are provided by the Société de Transport du Grand Angoulême (STGA). The city has 40 signalized intersections giving priority to buses, and has adopted a number of other bus priority measures including reserved lanes, bus-only streets, and bus-only turning movements.

Automatic Vehicle Location (AVL)

AVL is achieved by a radio link between buses and the bus control centre. Each bus is interrogated, at 20-second intervals, by a central computer in order to determine the bus position relative to its route. The system relies on knowing the position of a bus to within $\pm$ 10 m of its actual location on the road.

Signal Priority

Communication is based on a radio link between bus and the local intersection signal controller. The bus informs the signal controller both of its need for priority on approach, and of its passage through the intersection.

On receiving a request for priority, the local controller has two options, depending on the phase of the signal cycle - either to extend the green time to allow the bus to get across the intersection, or to speed up the phases so as to give the green light to the bus before its arrival at the stop line. These two operations are constrained by set minimum and maximum green times.

Reported Impacts

Of the 16 intersections studied, only two showed results that were not positive. The study established criteria for cases where priority at signalized intersections would, in fact, not bring any benefits.

Special Interest

Angoulême is a city which has an integrated system for its bus priority and bus monitoring/information systems.

It is implementing a new system for its town centre. This will add another 25 signalized intersections to the system, and will use radio links to communicate between bus, bus control centre, and traffic control centre (TCC). The role of the TCC in the town centre system will be to act as a regulator in deciding whether or not traffic conditions favour priority.

2. Nancy, France

Background

Nancy has a population of 250,000 inhabitants. The bus and articulated dual-mode trolley bus services are operated as a franchise by the Compagnie Générale Française de Transports et d'Entreprises (CGFTE) on behalf of the local authority. There are some 120 signalized intersections providing priority to public transport. Nancy also operates bus lanes and public transport only streets. The city has some 10 years of experience in transit priority at signalized intersections.

Automatic Vehicle Location (AVL)

AVL is achieved by radio link using two channels. One channel is used for voice communication between vehicles and the central computer. The second channel is used for cyclic (every 30 seconds) numeric data transmission from on-board vehicle equipment to the central computer. On-board equipment consists of a radio transmitter - receiver, a microprocessor, a wheel revolution counter, and a display device. The distance travelled from a terminal, determined by the number of wheel revolutions, enables the computer to locate the position of a vehicle on the road.

Signal Priority

For the area of the city controlled by the on-line UTC system, priority is achieved by two-way communication between the public transport central computer (PTCC), and the traffic signal central computer (TSCC). The PTCC, through its cyclic interrogation of transit vehicles, informs the TSCC when a transit vehicle is within

a defined approach zone of a signalized intersection. Before initiating priority, the TSCC interrogates the PTCC for an update on the location of the transit vehicle(s). On the basis of that latest information, the TSCC predicts the arrival of the transit vehicle at the intersection, and makes a decision on whether to extend a green phase or to opt for matching the arrival of the transit vehicle and the onset of the next green phase.

For isolated intersections, communication is by radio between the transit vehicle and a receiver situated in the cabinet of the local intersection signal controller.

Reported Impacts

On the basis of a "Before and After" study on a route representative of the network, the following results are reported:

- a saving of over 5% on average journey times; and
- a 40% increase in transit reliability defined as the number of arrivals within three minutes of expected time.

Special Interest

The mechanism of priority is provided via the traffic signal central computer.

3. Stuttgart, Germany

Background

Stuttgart has a population of some 560,000 inhabitants. The LRT system is the backbone of the city transit system, and is supported by bus service which acts as a feeder system and provides service to suburban areas outside the city itself. The city has implemented a number of transit priority measures including reserved lanes, queue jumpers and transit only turns.

Automatic Vehicle Location (AVL)

The automatic vehicle location system is a combination of beacons placed at strategic locations and a radio polling system. The LRT system is monitored by

inductive loops between the tracks. All information is routed through a modern central control centre and action taken as required.

Signal Priority

Request for priority at signalized intersections is achieved by direct communication between the transit vehicles and the local intersection signal controller. The central traffic control monitors malfunctions in the system only. Using a microwave beacon, the beacon receives information regarding the bus and transmits the request for priority to the local controller to provide priority. On passing the intersection, a second beacon receives data, terminates priority at its location and advises the next location of the approaching bus.

Reported Impacts

On the LRT systems, delay due to lost time at signals has been reduced from 12% to 2% of transit time. This is a result of all transit priority impacts including the inauguration of separate underground rights-of-way. No information was available on the impact of transit priority on the bus lines.

Special Interests

Stuttgart operates the popular German "Green Wave" traffic signal system which favours traffic along main roads and attempts to provide traffic progression through a series of signalized intersections.

4. London, UK

Background

Greater London has a population of some 6,700,000 inhabitants. It is served by both buses (London Buses Ltd.) and Metro (London Underground Ltd.). London has some 200 bus lanes, operating mostly at peak hours, some bus and taxi-only streets, and since 1991, it has piloted the "Red Route" scheme which consists of rigorous parking controls on some main roads into London.

Automatic Vehicle Location (AVL)

No automatic system is in place. All buses have two-way radio linked to a central communications centre, mainly for emergency use.

Signal Priority

Buses are equipped with transponders which, via an embedded inductive loop in the road, activate the local intersection signal controller to request priority. The intersections are predominantly isolated and under vehicle actuated control.

The control strategies include priority extension, priority recall, inhibit and compensation. Priority extension involves the extension of green time to allow a bus through an intersection, whilst priority recall involves changing a red signal to green, subject to some constraints, on the detection of a bus. Where non-priority stages suffer significant delays, the system adopts an inhibit facility, in which priority calls in consecutive cycles are denied and/or a compensation facility, in which the time lost to a non-priority stage due to a priority call is repaid in the following subsequent cycles.

Reported Impacts

These are based on a study conducted in 1987 in the outer London district of SELKENT (South East London and Kent), covering 56 signal controlled intersections and some 900 buses, fitted with transponders. Observations were made at 10 representative sites. The following is a summary of the main results:

- the average recorded bus delay saving was some nine seconds per bus;
- the average reduction in standard deviation (variability) was four seconds per bus;
- the average non-priority traffic delays were unaffected in off-peak periods, but increased by an average 2.7 seconds per vehicle during peak periods;
- re-location of bus stops caused significant delays to bus passengers, but was compensated by reductions in delay to general traffic, as a result of the relocation, and in bus delays at intersections; and

- it was estimated that the benefits from the scheme would exceed the total scheme costs, including the costs for development and evaluation, within two years of operation.

Special Interests

The London scheme is relatively new, and London Transport Planning has recent experience with the difficulties and problems of implementing a bus priority scheme in an old established city.

5. Zurich, Switzerland

Background

Zurich is an historic city of some 375,000 inhabitants. Its public transport services include bus, trolley bus, tram and LRT. Some 50% of its 280 priority signalized intersections are used by buses. Other priority measures adopted for public transport include reserved lanes, public transport-only streets, exclusive right-of-way, and public transport-only turning movements.

Automatic Vehicle Location (AVL)

AVL is achieved by cyclical (15-second intervals) interrogation of transit vehicles by the control room central computer (CRCC) via radio links. The on-board vehicle computer transmits two statements to the CRCC - the location code received from a roadside radio beacon as the vehicle passes the beacon, and the distance travelled as measured by the on-board odometer.

Signal Priority

Request for priority is achieved by communicating, to the traffic control centre, a vehicle's identify as the vehicle, equipped with an on-board transponder, crosses two embedded inductive loops located at fixed distances upstream of a set of traffic lights. A green phase is nearly guaranteed for transit vehicles as Zurich operates a "zero waiting time" policy at signalized intersections for its public transport. In cases where there are stops close to and before a signalized intersection, the signals turn to green some 10 to 15 seconds after the vehicle has been identified prior to stopping.

Zurich's traffic control system and its operational control system operate independently of each other.

Reported Impacts

The following results are reported:

- an annual public transport trip rate of 490 per person compared to 131, 250 and 290 for Manchester, Stuttgart and London, respectively;
- "zero waiting-time", for public transport, achieved at about 90% of signalized intersections; and
- reduced energy consumption, and an enhanced environment.

Special Interest

Zurich has some 20 years of experience in promoting and implementing the use of public transport, and appears to have been very successful. It is unique in that its program for improving its public transport services was, and is, supported not only by politicians and all agencies concerned, but also by the public through referenda.

It has an indigenous designed "decentralized" traffic control system.

It was believed that these cities would provide a broad range of conditions including city size, number of locations with transit priority, traffic control strategies, technology strategies, other priority strategies and good experience with the measurement of benefits.

3. CASE STUDIES-INTRODUCTION

Following the conclusion of the Task 1 report, and the review of information from additional cities in Germany (Osnabruck and Bochum), it was agreed that the following cities would be the subject of a more detailed analysis and field study:

London, England
Stuttgart, Germany
Zurich, Switzerland
Nancy, France
Angoulême, France

A detailed questionnaire was developed to gather information on specific elements of successful and less successful applications of transit priority at signalized intersections. Committee members had suggested that information could be collected for applications that included the operation of signal priority, both in association with reserved bus lanes and in mixed traffic operation. In actual practice, it was found that the questionnaire could act as a guide only, as the transit authorities could not, in all cases, break out a particular application from the overall system implementation. This is described in more detail under the individual City cases studies.

For the detailed case studies, arrangements were made to visit the individual cities and meet with both the transit representatives and traffic authorities. The visits took place during the first two weeks of June 1993. As mentioned, a detailed questionnaire was prepared to elicit the required information for each of the cities. Following below is an outline of the City, its transit system, traffic control, and priority measures used for transit. The description of transit priority is divided into two areas, namely, overall priority measures and specifically traffic signal priority for transit vehicles. The evaluation of the signal priority measures is described and a general cost provided for the installation and operation of the system where available.

The visit to the individual cities provided a wealth of information on transit priority. Comments are provided on the general observations related to transit priority made while riding the transit systems.

4. LONDON (ENGLAND) CASE STUDY

4.1 INTRODUCTION

London is a large cosmopolitan city with a population of over 6 million. The service area for London Transport and associated bus services is about 1,100 sq. miles, with the City of London being about 600 sq. miles. The topography of the area is generally flat along the east-west River Thames basin with hills to the north and south. The road system has developed on a radial scheme based on the historical development of the London area itself.

For the field study, the following people were interviewed:

Mr. Clive Muzzelle
Senior Transport Planner
London Transport Planning
55 Broadway
London SW1HOBD

Mr. James R. Landels, B.Sc.(Eng.)
Head of Traffic
Traffic Control Systems Unit
Kings Building
Smith Square, London
SWP 3HQ

Mr. G. Nigel King, B.Sc.
Traffic and Local Plans Manager
London Transport Planning
(provided a description of bus lanes)

Mr. S. Balogh
Corporate Planning and Policy Division
London Transport Planning
(provided a description of passenger information system)

4.2 TRANSIT SYSTEM

4.2.1 Organization

1) London Transport runs virtually all of the bus routes and underground network in London and is broken down as follows:

- London Buses

  London Buses Ltd. provide the majority of surface bus transit in the London area on approximately 1,800 miles of road. These services have been

broken down into 10-12 subsidiary companies which may be privatized in the near future.

- Tendered Buses

  For the 1991/92 fiscal year, 38% of service in the London area was provided by private contractors, including London Bus itself. The tendered service is likely to increase in percentage of the operation in the future.

- London Underground

  London Underground is responsible for all 245 of the underground (subway) services in London except the Waterloo and City lines (1-1/2 miles long) which are run by British Rail.

2) Docklands Light Rail

The Docklands Light Rail line was developed by London Transport to serve the new Docklands development, particularly Canary Wharf. The ownership of the railway was transferred to the London Docklands Development Corporation as of March 31, 1992.

3) British Rail

This is run by British Rail with tracks radiating from the centre of London to provide long haul and commuter services.

4.2.2 Key Statistics

Key system statistics are as follows:

1992/93	Buses in London	London Under-ground	Dockland*
Vehicles	6,138	9,146	70
Miles Operated	199 M	33.44 M (train miles)	0.6 M (train miles)
Passenger Journeys	1,127 M	728 M	7.0 M
Staff	16,665	19,014	490
Route Miles	1,870	245	8.5 M

*Note: Not operated weekends due to construction work. Not all vehicles in service awaiting the completion of the Beckton Extension which is scheduled to open in April 1994.

4.2.3 System Operation

As mentioned, the London Underground provides an extensive service throughout London and is based on a through London radial system with the Circle line connecting most of British Rail main line stations. It was explained that based on tunnelling construction, the southeast area of London is not as well served by the Underground due to the poor soil conditions prevalent in the area.

The bus service overlaps the underground service in many areas but does provide connections at many stations.

Zone tickets can be purchased which allow passengers to use different modes of transport within a specific zone or zones.

4.2.4 Automatic Vehicle Location

London Transport has been using Automatic Vehicle Location (AVL) to monitor and control part of its bus operation for many years. The AVL system uses microwave beacons, located at key points along the route, in association with an on-board transponder, wheel revolution counter and radio communication to provide details on the location of each bus in the system.

The microwave system for AVL is being extended to cover 600 buses. This will leave around 5500 without AVL.

London Transport is currently testing a system, called COUNTDOWN, for providing information to passengers on the expected arrival (in minutes) of the next bus(es). The system is already used in the underground and is expected to provide substantial benefits to bus riders. The total cost of the trial of COUNTDOWN (including AVL) on route 18 will be about £1.4M, which includes fitting equipment on all 33 buses serving the route. However, a large element of this cost is for development and market research, so an extension of the system would be much cheaper. It is estimated that a London-wide system covering about 100 major routes and 4,000 stops could cost about £35M. Operating costs are relatively small and would be proportionately less if more routes were added.

An earlier, more limited trial on route 36 in 1986-88 indicated that passengers put a high value on real-time information. On route 18 LT Planning have forecast passenger benefits worth nearly £1M per annum including extra journeys bringing in about £¼m per annum in additional revenue. The improved service control from AVL will bring further passenger benefits and revenue.

Extensive market research will be undertaken during the one-year demonstration period to establish more accurately the value of the system and to refine its operation to maximize passenger benefits and fare revenue.

4.3 TRAFFIC CONTROL

4.3.1 Organization

General traffic control has historically been supervised by the police. However, the Traffic Control Systems Unit (TCSU) of the City of London Engineer's Department provides the computer hardware and software expertise for system control. This group provides procedures for initiation by the police in specific circumstances.

There is a good relationship between London Transport and the TCSU dating back to their working relationship within the now disbanded Greater London Council. During that time, they worked together to initiate increased priority for transit. Each group is aware of the other's expertise and a mutual respect and trust has been developed. They believe that they can work together to address the major transport problems in the area.

4.3.2 Traffic Control Methods

There are approximately 3,500 traffic signals within the Greater London area, 1,400 of which are under central control. Within the City itself, 430 intersections come under the control of the SCOOT program which involves an offset optimization technique based on actual traffic conditions. With the SCOOT program, traffic is detected using a number of loops in the pavement approaching an intersection. The central computer analyzes the traffic flow and adjusts the signal timing accordingly on a continuous basis.

At central control, supervisors monitor the traffic flow through use of computer graphics, illustrating congested locations, and about 100 video cameras placed at strategic locations. The remainder of the traffic signals in the suburban areas are isolated intersections under fixed time control.

The general principle for traffic control in London is to minimize delay in the a.m. peak period for all traffic and provide outbound priority in the p.m. peak period.

4.3.3 Other Background Information

London is also developing what they call RED ROUTES. These routes are described as key arterial roadways where traffic flow is given clear priority. No stopping (buses excepted) is allowed for any reason on these routes. Places to stop for delivery vehicles, etc., have been provided such that they do not interfere with the general traffic flow. There are over 300 miles of RED ROUTES proposed in London, of which about 250 miles are used by bus routes.

For buses on the pilot RED ROUTE, there has been up to 25% savings in travel time on the routes, combined with a 9% increase in patronage when overall system ridership was declining by about 2%. At the present time, an additional 400 miles of bus routes are expected to be investigated to reduce bus delays by the use of bus priorities and other traffic management measures, including enforcement of parking restrictions. This and the RED ROUTES network would give a full ⅓ of the bus network priority status.

4.4 PUBLIC TRANSIT PRIORITY

4.4.1 Philosophy

The desire for the provision of priority for public transit vehicles has varied over the last 20 years. At the present time there is a strong commitment at all levels to try and reduce (at least not increase) private vehicle flow, particularly in the downtown area, and give more priority to buses.

In 1990, London Transport launched a program called "The London Bus Priority Initiative" with the aim of increasing the level of bus priority in Greater London. A steering group includes representation from the London boroughs, the Department of Transport, the Traffic Director for London, the Traffic Control Systems Unit, the Police and London Transport. A number of bus priority studies have been undertaken and improvements have been implemented. Further studies are now underway and it is expected that more priority measures for buses will be forthcoming.

4.4.2 Existing Priority Measures

The following priority measures are currently used in London.

Reserved Bus Lanes

There are currently over 170 reserved bus lane locations in London. These lanes total over 81 km in length and range from short queue jumpers to 3 km in length. The average is about 300 m and are basically "queue jumping" lanes.

The bus lanes are designated for priority vehicle use (buses, coaches, taxis, cycles) for various times throughout the day, depending on the congestion problems (normally 7-10 a.m., 4-7 p.m. with a few 7 am - 7 pm). All buses, taxis and bicycles are allowed to use the lanes.

The general policy is to discontinue the reserved lane shortly before the major intersections to maintain the intersection capacity but close enough to allow priority vehicles to get through in the next green phase.

London Transport estimates that the savings associated with reserved bus lanes amount to £20M/year and they generally give buses a higher profile and greater reliability. Overall delays

in London are estimated at £100M/yr. in bus operation costs and £120M/yr. in passenger delays.

Contra Flow Bus Lanes

There are about ten contra flow bus lanes in operation in London to counteract a one-way street restriction. In London, the two-way street principle has been increasingly used and bus lanes may be implemented on a portion or all of a congested street. Where space is limited the street/lane may be designated for buses only.

Bus Only Streets

Oxford Street, in the downtown core of London, is restricted to use by buses and taxis only, with private vehicle use for access to local points. There are over 240 buses/hr. using this stretch of Oxford Street.

Bus Only Turns

There are about 50 turn exemptions for buses in London mostly allowing a small number of buses to make a right turn.

Queue Jumpers

These facilities, which are basically short sections of reserved bus lanes, are included in the previous bus lane statistics.

Transit Priority at Signalized Intersections

Two experimental projects to provide priority for buses at non-linked signalized intersections were undertaken in the 1980's. These experiments indicated that a saving of 10 secs/bus at the signalized intersections could be realized with only minor (1 sec/veh.) delay to other vehicles. The South East London project in the late 1980's installed equipment at 56 intersections to provide priority for buses. The favourable results of this project have led to a 4 year scheme to expand this priority treatment to 300 more intersections around London. This program is expected to be completed by March 1994. London Transport/European research is ongoing to apply the system to linked signs (see Section 4.7).

Queue Relocation Techniques

London Transport is working with local traffic officials and the Traffic Signal Control Unit to develop innovative ways to reduce traffic congestion while providing priority for buses. These techniques are site specific and could involve a change in signal timing at a congested location, combined with a reserved bus lane, which relocates queues such that bus priority can be achieved through the congested areas. Examples of this strategy are shown in Appendix A-5.

Bus Pre-Signals

The bus pre-signal strategy is currently in the design stage and potential sites have been identified. The strategy involves the introduction of an additional signal some distance ahead of a main intersection. At this location, buses in a bus lane are given priority to start moving before the adjacent private vehicles. This allows the bus to get ahead of other traffic into a mixed traffic link or to pull across traffic to make a turn. A diagram of this strategy is shown in Appendix A-5.

4.5 TRAFFIC SIGNAL PRIORITY FOR TRANSIT VEHICLES

4.5.1 Mechanism for Signal Priority

At the present time, selective detection facilities to provide priority to buses has only been installed at isolated (non-linked) traffic signal locations. The detection takes place when a transponder on the bus responds to a signal from a loop in the road. The detection of the bus is then transmitted to the signal intersection box and priority is requested.

There is currently no interaction between the AVL system and signal priority system. A study is contemplated, however, to review the opportunity of using the AVL beacons to provide the signal priority detection and to limit the call for priority to late vehicles only.

The vehicle detection loop is generally located approximately 70 m from the intersection or 8-10 seconds travel time. An attempt has been made, where possible, to relocate stops from preferred near side locations to midblock or farside locations to obtain greater benefit from the priority call. No allowance has been made for passenger service time because of its variability.

The loop location and requirement for a second loop are determined on a site by site basis. In some cases the loop is placed immediately downstream of the stop to trigger priority. In a few cases, the loop would be placed upstream to call for a green signal to clear traffic in front of the bus.

A key point made regarding location is that the loop must be at least 5 m away from other traffic loops and manhole covers.

4.5.2 Priority Strategies Used

Both green extension and red truncation are used to reduce bus delays. The strategies are in place 24 hours per day. Inhibit facilities can be used in some cases during peak periods with high bus/car flows to minimize disbenefits to non-priority traffic.

Priority can be requested on all four arms of an intersection. Of the 350 intersections considered, 1/3 to 1/2 will have cross routes. The maximum green extension is 15 seconds while the minimum green provided on the cross street during red truncation is 7 seconds. Some compensation is provided to the cross street after red truncation. However, no compensation is given following green extension.

There is no mechanism to shut off the green extension or red truncation following passage of the bus through the intersection.

4.5.3 Criteria for Site Selection

London Transport and the Traffic Control Systems Unit have not developed clear criteria for installation of signal priority for the buses. Their main objective is to reduce bus delay wherever it is occurring and they have developed the following procedure to determine overall benefits compared to costs.

Site Selection Procedure: Outline Summary

1. Restrict selective detection (S.D.) application to isolated intersections under vehicle extension.

2. Determine potential leg(s) of intersection for S.D.

3. Determine detector locations/bus stop relocation requirements

4. Estimate detection/equipment costs.

5. Check for possible operational problems.

6. Consider control strategies and signal optimization.

7. Estimate S.D. benefits from signal timings/bus flows amended as necessary from steps 3, 5 and 6 above (see Section 4.6.1).

London Transport believes that they can gain benefits from intersections that have up to 40 buses/hr. on the minor arm and 40-50 buses/hr on the major arm. They have yet to reach this level for a minor arm.

Current locations include minimum bus volumes of 5/hr. with up to 2000+ passenger car units per lane of private vehicles. The traffic control staff believe that signal priority works better in suburban areas with fewer buses (i.e. downtown may have › 100 buses/hr per location). In addition, they believe that they have a better chance of effectiveness with reserved lanes.

4.5.4 Process of Implementation

The idea to provide priority for buses at signalized intersections in London started when London Transport and the signals group worked together as part of the Greater London Council. The idea, on approval of the London politicians, translated into two pilot projects, one in the early 1980's at seven intersections in Hounslow, followed by a larger experiment in South East London involving 56 intersections. The results of these two projects indicated that there were significant benefits to be gained. The cost/benefit analysis, as discussed below, indicated a very high rate of return.

It has now been agreed to expand the priority system to 300 more signalized intersections around the London area by 1994. The cost of the total program is estimated to be £3.5M. It has been estimated that the system will pay for itself in savings within 15 months.

The program is managed by London Transport and the Traffic Control Systems Unit (TCSU). The cost is shared ⅓ London Transport and ⅔ TCSU as follows:

London Transport - obtains the transponders, fits the unit on the bus, and installs testing equipment at local garages.

TCSU - undertakes the design of each installation, obtains and installs the detector equipment and connects to signal box, obtains and installs interrogator in intersection box and commissions each site.

From their previous relations at the Greater London Council, the two groups work together with a mutual respect for each other's expertise.

To date, there have not been any major problems with the installations. It is likely that the system will be expanded further as there is a strong political will to reduce vehicle flow in the downtown area and increase priority for transit. Future plans are discussed later.

4.6 EVALUATION

4.6.1 Definition of Methodology

The evaluation is based on the SELKENT (South East London and Kent) study, covering 56 signalized intersections and including the fitting of some 900 London buses with transponders to activate priority. The evaluation of the system was based on before and after data collected at a representative 10 sites (of 56 installed) during the autumn/winter of 1987/88.

A full cost benefit analysis was undertaken considering the following items:

System Costs

Note: The British pound (£) is approximately $2.00 Canadian.

The main items to be considered are listed below, along with typical costs for London (excluding development/evaluation):

i) Purchase/fitting of transponders to buses (~ £116/unit)
ii) Installation of loops/cabling (~ £1,200 per arm for 70 m detector)
iii) Detection units (~ £1,500 for first two units at an intersection, then £350 for each additional unit)
iv) Garage transponder testing equipment (~ £6,000/garage)
v) Commissioning/running costs (cost not provided)
vi) Maintenance costs (~ £500/site/annum).

As an example, the equipping of 5,000 buses and 330 sites in outer London would cost around £3,500 per intersection approach. With a fixed number of buses equipped, the cost per intersection decreases as more intersections are added to the system (as the cost of transponders is spread over more intersections).

System Benefits

The economic benefits include the effects of S.D. on:

i) Bus passenger delay
ii) General traffic delay
iii) Vehicle operating costs
iv) Delay variability (buses and general traffic)
v) Pedestrian delay
vi) Bus passenger walking times and traffic delays due to relocated bus stops
vii) Bus crew costs
viii) Bus operating costs.

4.6.2 Evaluation Results

The average recorded bus delay saving due to selective detection was some 9 secs/bus (or 32% of delay), being some 11 and 8 secs/bus for peak and off-peak periods respectively. The average reduction in standard deviation (variability) was 4 secs/bus (or 22%), this being similar between the different time periods. However, there was considerable between-site variability in both parameters. Average non-priority traffic delays were unaffected in off-peak periods but increased by an average of 2.7 secs/vehicle during peak periods.

The effects on average pedestrian delays were minimal, while bus passenger walking times to bus stops relocated further upstream increased substantially. However, it was estimated that these were largely offset by reductions in delay to general traffic due to the relocation of the bus stops. Automatic monitoring of the system in operation showed it to be functioning satisfactorily in terms of the expected number of priority calls and signal response, although longer term monitoring would be required to assess reliability.

Scheme installation costs totalled some £515k, including development and evaluation costs. Total annual benefits were estimated at some £750k (or £900k for off-peak periods only), the scheme having a net present value of around £3M over a 7-year evaluation period assuming constant annual benefits.

The extension of selective detection to the remainder of outer London (a further 275 intersections) produces a higher return than SELKENT, on the assumption that the cost of transponders would reduce and there would be no development/evaluation costs. Assuming also that bus services and current methods of signal control remain stable, the Internal Rate of Return over 7 years for SELKENT of 90%/annum would increase to around 125% for the remainder of outer London.

The scheme is estimated to pay for itself within 15 months of full operation. This is considered to be a good pay back period in traffic management circles.

4.6.3 Longer Term Experience

London Transport has continued with the signal priority scheme and expansion to 300 other locations in outer London. No location has been considered unsuccessful. The only reason for removal has been if an intersection was included in the linked system under central control.

4.6.4 Costs

Typical unit costs were shown under the evaluation, Section 4.6.1. Discussion with London Transport officials indicated an update on the broader costs of the installation. These figures are as follows:

Transponders (per unit)		- £ 180
Additional garage test sites and installation of transponder (by private company)		- £7,000 per site
Equipment at signals		- £8,000 per intersection
Annual maintenance	(existing)	- £5,000
	(future)	- £0,000

The cost to extend the scheme by a further 300 intersections is estimated to be £3.5M in total to be spread over a four year period.

4.7 FUTURE PLANS

At the present time, bus priority at traffic signals cannot be incorporated within any of the intersections under SCOOT control. In the past, it was considered that incorporation of bus priority within the SCOOT network could result in losing the benefit for transit due to the delay by the computer in making a decision.

As part of the European Community DRIVE project, PROMPT (Priority and Informatics in Public Transport), the provision of active bus priority within the SCOOT traffic responsive control system is presently being developed. The main objectives of this project are to:

- Improve the efficiency of traffic networks, particularly public transport systems and monitor the range of effects including safety and environmental benefits.
- Assess the effectiveness of Selective Vehicle Detection* in adaptive UTC systems.
- Assess and evaluate the achievable levels of bus priority within an operational SCOOT UTC system.
- Evaluate the effects of bus priority on all classes of vehicles.
- Provide recommendations for bus priority system designs.
- Define user requirements and possible control strategies. Compare systems and techniques in London with other cities participating in the project (principally Turin and Gothenburg).
- Evaluate alternative techniques and select the most appropriate system for public transport priority and UTC.
- Verify the suitability of systems developed in London field trials to other European cities.

*Note: It has been suggested that the method of detection for the future will more likely be microwave (AVL) or infrared rather than SVD.

A report on a pilot project is expected by late 1994.

Secondly, consideration is also being given to the integration of the AVL system and the traffic signal priority system. The beacons currently being used for the AVL system could be tied to the signal system to provide priority only for buses that are late.

Another option which may be considered is to use the AVL radio to talk directly to the traffic signal controllers.

Both of these options are subject to detailed study.

4.8 SUMMARY OF INSTALLATION

The installation of priority for transit at signalized intersections appears to be a success. Although full priority is not provided, the benefits have been estimated as substantial and clearly provide significant savings for passengers on London Transport buses.

Priority treatment for London Transport buses is an evolving process. Bus lanes have been provided in key locations since the late 1960's and additional installations have been incorporated in the system over the last 25 years. Bus priority has come later and the two may or may not be combined depending on the situation.

Based on current projects, it appears that bus priority will continue to grow. The only questions are where and how fast.

4.9 OBSERVATIONS

Because of the strategies used in London, it was difficult to observe the level of priority given to buses at the test sites. An observation in Hounslow illustrated that buses were not significantly delayed at signalized intersections. However, because of the high volume of buses, it was not possible to tell if a bus was receiving priority at a particular location or not.

Bus lane observations on Park Lane and Oxford Street indicated significant benefit to buses where heavy traffic flows are evident. Oxford Street, as a bus-only street (with taxis and limited private vehicles), would be unbearable if private vehicles were allowed on the streets. The volume of buses is such that they cause significant congestion on their own.

5. STUTTGART (GERMANY) CASE STUDY

5.1 INTRODUCTION

Stuttgart is a medium sized city with a regional population of about 560,000. The service area for transit covers approximately 527 sq. km, of which 207 square km make up the City of Stuttgart. The main centre of Stuttgart is located in a valley on the Neckar River. Suburban development has expanded outside of the valley and transit serves a number of other smaller municipalities and villages. Because of the topography, the road system has developed on radial basis through the centre of the valley and up to the surrounding municipal areas.

For the field study, the following person was interviewed and provided a tour of the signal priority installation, the traffic control centre and the transit control centre:

Dr. Ing. W. Laubert
Transport Manager - Traffic Engineering
Stuttgarter Strassenbahnen AG
Postfach 801006
70510 Stuttgart
Germany

5.2 TRANSIT SYSTEM

5.2.1 Organization

Transit in the Stuttgart area is provided by a separate company called Stuttgarter Strassenbahnen AG (SSB) with their own Board of Directors. The Board is comprised of 50% politicians and 50% delegates from the regional political parties. The Board meets four times per year to discuss performance of the system and to approve major expenditures related to such things as bus/LRT purchases or construction. The Board also approves the company's budget annually.

There are three levels of government involved in transit, with each providing some financial contribution. They are:

i) City
ii) State
iii) Federal

Proposals generated by the SSB are approved by the individual levels of government for funding. Subsequently they follow the progress of the project and report on the achievement of the forecast benefits.

5.2.2 Key Statistics

Key system statistics area:

1992	LRT	TRAMS	BUSES	TOTAL
Vehicles	100 double train (16 on order)	150	290	459
Kms Operated	6.5 M	10.1 M	15.5 M	32.1 M
Passenger Journeys	59.0 M	42.1 M	53.9 M	155.0 M
Staff	297	265	756	1,318
Route Kms	74.6	35.4	430.3	539.4

5.2.3 System Operation

Transit service in the Stuttgart area is provided by commuter rail to the outlying areas, LRT and trams which operate basically within the City of Stuttgart itself, and buses which complement the LRT/train service and extend to the outlying municipalities and villages. There is a number of connections throughout Stuttgart between the local service and the commuter rail service. In the other communities, bus service is also provided by other bus companies. There is fare integration between all of the services which is funded by the state government.

5.2.4 Automatic Vehicle Location

Stuttgart's AVL system for surface bus routes is based on a series of beacons placed at strategic locations, wheel revolution measurement and a radio polling system. Operators are advised if they are ahead or behind their schedule. SSB has based their traffic signal priority system on similar equipment to the AVL system.

5.3 TRAFFIC CONTROL

5.3.1 Organization

Each of the individual communities around Stuttgart control their own signals. Within Stuttgart, the traffic signals are under the control of the Transportation Department.

5.3.2 Traffic Control Methods

There are approximately 655 traffic signals in Stuttgart. Their old technique involved central control for all signals. Their newer technique has been to develop networking with local control. The central control only changes the overall system strategies (i.e. inbound, outbound, time of day, etc.).

At central control, staff only monitor the system to ensure that there are no problems with signals not working or bulbs that may burn out.

The signal system philosophy is to minimize vehicular delays. This is achieved by providing priority in peak directions for main arterial roads and co-ordinating flow in all directions in other areas.

5.4. PUBLIC TRANSIT PRIORITY

5.4.1 Philosophy

The philosophy in Stuttgart is to attract as many people to transit as possible. There is a policy to build as few new roads as possible in the area. However, there is pressure to connect the circumferential highway system through the central area to reduce travel times.

Modal split during the peak hours for people travelling into the central area is about 40%, including commuter rail. The commuter rail network is operating at about 110% of capacity at the present time. While there is a desire to improve service, it would be very expensive.

In the meantime, efforts have been made to improve the attractiveness of local transit by improving travel times.

5.4.2 Existing Priority Measures

The following priority measures are currently used in Stuttgart.

Reserved Bus Lanes

Reserved bus lanes in Stuttgart are the exception rather than the rule. The development of the LRT underground system in Stuttgart has taken many of the trams off the roads in the central area. Current reserved lane installations act more like queue jumpers to allow buses to avoid congestion at an intersection.

Tram lines in the downtown area, which have not been converted to underground operation, generally operate in mixed traffic on the surface. In the suburban areas, most surface lines operate in their own rights-of-way either in the centre or on the side of the road.

Transit Priority at Signalized Intersections

Signal priority for transit vehicles in Stuttgart began with the desire to reduce delay due to traffic signals on the LRT system by 50%. This has been achieved over time not only by developing separate rights-of-way for LRT routes, but also by giving LRT vehicles full signal pre-emption at signalized intersections where necessary.

Information (1991) on the LRT and tram line signal priority treatment is as follows:

Total number of traffic lights in Stuttgart	:	655
Total number of traffic lights with LRT or tramway participation (separate and mixed right-of-way)	:	190
Total number of traffic lights with LRT participation	:	110
Traffic lights with full pre-emption	:	95

Traffic lights with limited pre-emption (Green extension only) : 15

The transit priority treatment for LRT and tram lines resulted in a significant reduction in delay due to traffic signals. The ultimate objective is to provide absolute preferential treatment without any delay caused by the traffic light system.

As a result of the success with LRT and tram operation, the next step was to develop a system to provide transit priority at signals for buses. A test of seven (7) signal locations on a minor bus route was undertaken. The results of this test have led to plans to expand the network of signal priority for transit to another bus route which has 37 traffic signals along its route.

5.5 TRAFFIC SIGNAL PRIORITY FOR TRANSIT VEHICLES

5.5.1 Mechanism for Signal Priority

For the LRT, vehicle location and call for signal priority is completed through track detection and the signal system.

For buses, it is intended to co-ordinate the AVLC equipment and the traffic signal priority equipment using infrared beacons. Stuttgart has equipped much of its system with AVLC equipment using an IRIS device (infrared information system) on the bus, which sends a telegram to a stationary receiver positioned at key locations. The same type of equipment is being used for the signal priority test project.

The technical equipment necessary to implement signal priority for buses has already evolved over the short period of installation.

The infrared receiver must be installed a sufficient distance in front of the intersection. For the test route, this has been up to 300 m. The long distance has been based on the speed of the bus and the need for the intersection controller to make a decision and adjust other phases so priority can be provided.

The infrared beam receives an infrared transmission signal sent by the bus as it passes by. This transmission signal contains information on the line, route and destination identification of the bus. Using the AVLC system, information regarding how late the bus is running can be transmitted. Information on the line number, course and destination is important for signal

control at all intersections where buses are travelling in different directions or are to be otherwise handled differently.

The data received by the infrared beam are relayed by cable to the intersection control device where the data are processed and modifications in the signal control are initiated as needed. Immediately after the bus passes the traffic light, it sends a departure message via another infrared beam. Thus, at least two stationary infrared beams must be provided on each arm of the intersection with bus traffic.

The wire connection from the infrared beacon to the traffic signal controller has proven to be costly and somewhat unreliable. SSB is now changing their system to use a radio link from the bus to a battery operated receiver in the controller.

The radio link option is significantly less costly at 8,600 DM per intersection plus a one-time 30,000 DM cost for hardware and software versus 38,000 DM per each individual arm of an intersection for the wire connection. (The German DM is approximately $.90 Canadian)

The radio connection also allows the bus to update its position as it approaches the intersection using the AVLC information. This would allow the signal to adjust strategies if necessary when a bus is delayed by traffic, etc.

Dr. Laubert stressed the importance of collecting data on travel time for schedule/AVLC/delay analysis. The AVLC system breaks minutes into 6 sec. intervals. This level of data is not sufficient for traffic control and therefore SSB has developed a black box placed on each vehicle to collect data every second. This data includes information on speed, wheel revolutions, door openings, etc. The information can be collected for a 38 hour period. It is regularly downloaded from the black box and analyzed separately.

5.5.2 Priority Strategies Used

Green extension, red truncation and cycle interrupt strategies can be used at the priority locations. The strategies are in place 24 hours per day.

Priority can be called on all four arms of an intersection. The maximum red allowed on the cross street is 120 sec. The minimum green provided on the main street is 8 sec. and 5 sec. on the minor street. The amount of priority can vary by location as the vehicle advises the system when it has passed through the intersection. At a pedestrian crossing signal, the maximum wait for anyone crossing the street would be 90 sec. The minimum pedestrian green time is based on 2/3 of the time required to cross at 1.2m/sec walking speed.

Priority is provided on every request (at least in the initial test). This decision is made by the local controller by adjusting other phases. Following the priority call, an adjustment is made to the cross street green.

5.5.3 Criteria for Site Selection

The selection of Route 60 for the initial test was based on the fact that it was a simple route and had only 2 (out of 7) signalized intersections with cross traffic. It allowed the development and testing of the equipment and software with minimal adverse effects on local traffic. It also was operated with the new articulated buses which are already equipped with necessary vehicular equipment (IRIS) for traffic signal priority.

The next route (#42) to be equipped is based on the following criteria:

- It has the most traffic lights along the road (37).
- It has the highest lost time due to signals.
- It carries more passengers than any other SSB bus line, therefore benefits are likely to be greater.
- buses running on the line are already equipped with the necessary equipment for traffic signal priority.

The route currently operates on a 6 min. headway or 10 buses/hr. The maximum private vehicle flow on any cross street is 1,200 veh/hr.

5.5.4 Process of Implementation

The idea to implement signal priority came from transportation management and was approved by the politicians. The SSB worked closely with a variety of other City departments in the implementation of all transit priority measures. The departments involved include:

- SSB (the transit authority)
- planning
- transportation, including traffic engineering and construction engineering
- police
- parks - more so for reserved right-of-way operation
- City legal department.

The original test was paid for by the City. However, future installations are likely to be funded by State agencies and there is strong competition for funds.

The departments within Stuttgart work well together and there has been general agreement that transit will receive greater priority. The SSB takes the lead role to coordinate implementation. If there is agreement at the lower levels the project proceeds. If there is disagreement the heads of the various agencies meet to come to some agreement. There is strong political support for transit priority and rules have been developed to guide the agencies' actions.

5.6 EVALUATION

5.6.1 Definition of Methodology

As mentioned, the initial test for transit priority at signalized intersections was not based on expected beneficial results. Therefore, no defined criteria were developed to evaluate such benefits.

For the next application, the route with the worst delays and highest passenger volume has been selected. It will be the subject of future evaluation although estimates have been made of costs and benefits as outlined below.

5.6.2 Evaluation Results

On the initial test location (Route 60) with limited intersections having cross streets, there was no savings recorded in running time since signal delays were limited. Buses did appear, however, to be running closer to schedule, particularly during the peak hour when most of the delay problems occur. In addition, it was observed that there were no additional delays encountered by private vehicles along the route.

For line 42, based on a conservative assumption that 50% of the delay can be eliminated, it has been estimated that 8 minutes can be saved on an 84-minute running time (13 sec. per intersection). This would result in a saving of 2-3 vehicles on the route.

5.6.3 Longer Term Experience

Due to the short duration of this project, no long term experience can be reported. However, experience on the tram lines is significant. The original goal was to reduce delay at signals by 50%. The average delay for signals was 12-15% of running time. That average is now 1-2% with a maximum of 3%. The best example is a total of 25 seconds of traffic signal

delay on an 18 km route. This does, however, include sections which have been converted to underground operation.

5.6.4 Costs

Costs* reported for the trial system and future expansion are as follows:

i) Initial Installation

Description
- 1.8 km.
- 7 intersections, 2 of which have cross streets. Five (5) are pedestrian crossings only activated by push button. No cross bus routes were involved.
- a mixture of near and farside stops is used.

Total Cost (1991) - 1.8 M DM.

ii) Proposed Installation

Description
- 8.0 km
- 27 (of 37) intersections to be equipped along the route
- 7 cross routes.

Total Cost (1993) - 8.0 M DM.

Cost savings estimated for this project 600,000 DM annually, plus a reduction of 2-3 buses at 250,000 DM/bus.

*Note: The German deutschmark is approximately $.90 Canadian.

5.7 FUTURE PLANS

After equipping traffic lights for pre-emption treatment of buses on line 42, the traffic lights on other bus lines will also be retrofitted. The goal of the SSB is to have traffic signal priority for buses at as many traffic lights as possible. It is expected that it will take many years for all SBB buses to be provided with the necessary equipment for traffic signal priority because only newly acquired buses are being equipped.

5.8. SUMMARY OF INSTALLATION

The experience that Stuttgart had with minimizing delays at signalized intersections used by LRT and trams has led to continued efforts to expand the system to bus services.

The current installation has allowed the SBB to gain experience with the hardware and software and to make changes for future installations.

Based on the existing and proposed projects, it appears that bus priority will continue to grow. The long term desire is to create a signal control policy that allows for the public transit vehicle to acquire absolute priority as much as possible with an acceptable upper limit delay to other road users.

5.9 OBSERVATIONS

The test route (#60) location was in an older area of the City with narrow streets providing one lane in each direction. Much of the route is on a grade as it moves from the valley to the higher areas.

As mentioned, 5 out of 7 of the traffic signals are for pedestrians and are demand actuated. Regardless, the bus trip along the route was not delayed at any of the signal points.

6. ZURICH (SWITZERLAND) CASE STUDY

6.1 INTRODUCTION

Zurich is a medium-sized city with a service area population of about 550,000. There are approximately 360,000 people living within the City of Zurich itself. Zurich is built around a lake with the majority of development being to the north. The service area spreads out over a 30 km radius from the City. The topography extended from the lake is somewhat hilly and the road system has developed on a radial nature out from the City centre.

During the field trip, the following people were interviewed. The trip included a short movie about Zurich transit, a tour of the transit control centre, a field trip to view some key locations, and a visit to the police (traffic) control centre.

Dipl. Ing. Ernst Joos
Deputy Director
Zurich Transport Authority
Abteilung Betrieb
5th Floor
Luggwegstrasse, 65
8048 Zurich, Switzerland

E. Berger
Leiter Betriebsstab
Verkehrsbetriebe Zurich
Abteilung Betrieb
5th Floor, Office 503
Luggwegstrasse, 65
8049 Zurich
Switzerland

H.H. Stadlmann/H. Matthys
Stadlpolizi; Zurich
Abteilung Verkdehrsteuerung
Muhlegase 18
8001 Zurich
Switzerland

6.2 TRANSIT SYSTEM

6.2.1 Organization

The Zurich Transport Authority acts as a department within the City of Zurich. The police department is responsible for all aspects of traffic flow, including signals. A civil works branch is responsible for all construction. To accomplish improvement to transit requires the co-operation of all three groups.

A working group made up of representatives of each of the departments, develop solutions to transportation problems. If there is no agreement within the working group, a political decision is made by representatives of each of the groups plus the directors from each department.

For the past 20 years, the transport policy of the Council of the City of Zurich has had four main objectives:

- Promoting a change from the car to public environmentally-friendly transport.
- Channelling motor traffic - creating quieter conditions in residential areas.
- Limiting the parking places for commuters.
- Reducing motor traffic in the city. This objective of generally reducing the motor traffic was first formulated with this stringency in 1987 - under the impetus that atmospheric pollution was increasing.

The foregoing has led to transit being considered as a first priority.

6.2.2 Key Statistics

1991	Trams (Arctic)	Trolleys (Arctic)	Buses (Arctic)	Total
Vehicles	387 (188)	66 (66)	249 (62)	700
Km Operated	20.52 M	384 M	14.64 M	39.0 M
Journeys	N/A	N/A	N/A	310 M
Staff	N/A	N/A	N/A	2,798
Route Kms. - City - Region	117.3 -	36.3 -	116.3 235.4	269.9 235.4

6.2.3 System Operation

The Zurich transport system provides transit service within the City and to the surrounding region. Trams and trolley bus routes provide service within the City itself. Bus routes complement these services and extend beyond the City limits to municipalities within the

County. There are private bus companies which also operate in the outlying areas. An extensive commuter rail service provide stops throughout the regional area and beyond.

The fare system between all companies, including the railway, is integrated. For example, you can use your transit ticket to travel by commuter train within the City of Zurich proper.

6.2.4 Automatic Vehicle Location (AVL)

Zurich's AVL system for surface routes is based on a series of beacons placed at strategic locations along a route, an odometer impulse transmitter which continuously adds the distance from the last beacon, and a radio polling system which talks to the control centre about every 12 seconds. The driver is advised if and how much he is off schedule and can adjust accordingly, promoting schedule adherence.

The system that controls traffic lights is independent from the operational control system. Therefore, every train or bus benefits, regardless of whether it is on schedule.

6.3 TRAFFIC CONTROL

6.3.1 Organization

The police department is responsible for all areas of traffic control including signals. The policy for traffic control within the City is that traffic management must be undertaken within the existing space. No buildings can be torn down to provide traffic movement. This policy has resulted in the development of a close working relationship between the police and the public transport authority to promote transit usage.

The section of the police department responsible for traffic control is comprised of 20-25 people who are mostly electrical and computer engineers. They are responsible for control of lane configuration, traffic signals, software design and response to public complaints.

As mentioned, the police have a good working relationship with the transport authority. They work together to develop solutions to traffic problems that will help overall traffic flow. The police believe that helping transit vehicles move more quickly reduces their overall problems. An integral part of the relationship is a quarterly meeting with transit drivers to discuss problem areas.

6.3.2 Traffic Control Measures

There are approximately 380 traffic control signals in the City of Zurich. The City is divided into seven areas of signal control. Each area of up to 80 traffic signals is controlled by a microcomputer with a backup in case of failure. There is a central master computer that co-ordinates the seven areas and serves, in particular, for storage of operational data, detection of system faults and continuous counting of traffic. It also serves as the centre for developing new programs for implementation throughout the system. The Zurich officials believe that central control works best for them and have no plans to convert to isolated intersection control.

The overall traffic management policy is to manage all traffic flow but give priority to transit vehicles whenever possible. The idea is to have no congestion within the system. An extensive loop system allows traffic flows to be continuously monitored. Green waves are provided for trams and buses but not private vehicles. All the traffic management solutions are based on keeping all traffic moving, particularly the public transit vehicles.

Zurich officials believe that traffic management plans should be based on the level of traffic rather than time of day or day of week. Their continuous traffic counting program allows them to monitor flow and adjust their control accordingly.

6.3.3 Other Background Information

A key to traffic control in Zurich is the recognition that traffic flow is dynamic and must be monitored continually in order to adjust traffic management programs. For example, up-to-date information is kept on accidents. If a trend is observed, new programs of control are created in an attempt to alleviate the problem. They can be tested in a simulation program and implemented quickly.

The AVL system control includes a response scenario for almost every conceivable problem that could occur. Depending on the emergency, a check list has been prepared that outlines individual action the controller must take in response. He virtually reaches into a drawer and pulls out an action plan suited to his problem.

6.4 PUBLIC TRANSIT PRIORITY

6.4.1 Philosophy

The philosophy of providing priority for transit vehicles in Zurich relates back to the result of a referendum on subway construction in 1973. At that time, the public indicated that they were not in favour of implementing a program of underground lines through the City. The problems identified related to cost, preference for above ground operation and wider station spacing for underground stations.

Based on this result, City officials had to rethink their approach to traffic flow and provide greater emphasis for the use of public transit. As mentioned earlier, the primary policy is to improve public transit to such a degree that it is a viable option to the private car and therefore attracts a large portion of travellers. This policy has gradually led to a priority for travellers as follows:

- public transit
- bicycles
- pedestrians
- private vehicles

The analysis of traffic flow solutions is based on this priority order ranking. The guidelines for solutions are:

- give priority to transit vehicles, if possible.
- consider number of cars.
- consider number of pedestrians.
- consider result of solution upstream and downstream (i.e. avoid congestion and impacts on transit vehicles).

6.4.2 Existing Priority Measures

The policy of providing transit vehicles with priority has led to the implementation of a wide variety of measures depending on the local conditions.

The following measures are currently in use in Zurich.

Reserved Lanes

The tram lines within Zurich have priority over other traffic. Private vehicles are restricted from travel on the road surface delineated for tram use. Vehicles are allowed to cross the tracks to access local streets but are not allowed to delay the trams. If there is an area where both trams and vehicles must share the road space, the trams are given first priority to travel over the joint use section.

There are approximately 20 km of reserved bus lanes in Zurich, 12 km of which are shared with the trams. These sections vary in length. There is one example where one bus line uses a single bus lane for two-way operation. In this case, the service is a maximum 6 mins. headway and a signal controls entry into the bus lanes at each end.

Contra Flow Bus Lanes

The previous two-way bus lane might also be considered as a contra flow lane as it operates against opposing traffic in one direction.

Transit Only Streets

Hochbahnhof Strasse, the main downtown shopping street in Zurich, is restricted to tram vehicles only. Many of the tram lines use this street through the downtown area.

Bus Only Turns

A number of bus only turns are provided with a separate left turn lane and a separate signal to provide priority movement for buses.

Queue Jumpers

These facilities, which are basically short sections of reserved lanes, in association with signal priority, provide buses with a head start over other traffic.

Transit Priority at Signalized Intersections

Zurich's policy of providing priority for transit vehicles has led to a wide variety of applications of priority at signalized intersections. These include:

- full priority for trams at nearly all signalized intersections, i.e. - no delay.

- full priority for buses at signalized intersections, where possible.
- priority for a bus to enter or leave a reserved lane section.
- bus only turn lane with signal priority.
- signal timing which clears traffic in front of a bus exiting a reserved lane section.

Priority for Buses Entering Traffic

By law, autos must give buses the opportunity to move into traffic either from a bus bay or when changing lanes. It was recognized that this is difficult to enforce.

6.5 TRAFFIC SIGNAL PRIORITY FOR TRANSIT VEHICLES

6.5.1 Mechanism for Signal Priority

Of the nearly 400 signals in Zurich, approximately 300 have transit lines passing through them. Approximately 2,000 detectors have been installed to identify that a particular transit vehicle is approaching and requires priority at the signal. The transit vehicle information is transmitted from the detector via hardwire to the signal intersection box which in turn relays information to one of the central zonal computers. The analysis is completed considering all the implications based on other input and priority is granted if possible, as the vehicle arrives. A transponder on board the transit vehicles signals information to the loop as to the route of the vehicle.

Separate signal heads are provided for the transit vehicle to indicate that they can or cannot proceed. At locations where both trams and buses pass through the intersection, separate signals for each are provided.

Up to four (4) detection loops could be provided on each arm of an intersection. The first loop, approximately 200 m upstream, provides the initial information on the vehicle. The next loop updates the information and confirms how fast the vehicle is approaching. Depending on the location, a third loop may be installed for updating. Finally, a fourth loop confirms that the vehicle has passed through the intersection. At the same time the signal at the next intersection is advised that a transit vehicle is approaching. Loops in the roadway also provide continuous information on the number of private vehicles on a particular link. In this way the

computer is able to adjust cycle lengths and green time to the level of traffic demand while providing priority for the transit vehicles. When no transit vehicle is detected more green time is given to private vehicles and pedestrians.

The ultimate waiting time objective is zero for the transit vehicle. At nearside stops, passenger service time is allowed and the last loop prior to the intersection is activated by the door closing.

The police officials pointed out that the process and analysis is very complicated. It requires continuous monitoring of delays and passenger service time so that appropriate changes/updates can be made to the priority algorithm. Based on this information algorithms have been developed for nearside stops to allow for passenger service time including secondary boarding requirements. The activator of the priority strategy is tied to the door closing.

6.5.2 Priority Strategies Used

Both green extension and red truncation are used to reduce/eliminate delays. The strategies are in place 24 hours per day. In areas of high auto flows, zero delay is not always possible.

Priority can be requested on all four arms (or more) of an intersection. For trams, first come, first served is in effect. For buses, first come, first served rule is in effect, unless there is a tram for which first priority is given. Headways are generally 6 min. during peak hours on individual lines. On the Hauptbahnhof Strasse in the downtown, four lines operate together and priority is provided. Private vehicles crossing this street are about 800 vehicles/hour at the major intersections. The minimum green given is 5 seconds and the maximum is 20 seconds. The minimum green for pedestrians is 5 seconds and 8 seconds for autos. The minimum pedestrian time is calculated for the width of the street or to an island using a walking speed of 1.2m/sec.

Some compensation is provided for the side street, if possible, following a priority call. In general, the cycle lengths are short (50-60 seconds/cycle) and not more than 90-100 seconds.

6.5.3 Criteria for Site Selection

The policy in Zurich is to provide priority to transit vehicles whenever possible. Of the nearly 300 signalized intersections with tram and bus routes passing through, about 225 are equipped to provide priority to the public transit vehicles. Gradually, all of the intersections

will be equipped. As mentioned earlier, consideration is given to the individual locations and conditions in developing a solution to congestion. Generally, priority is given where possible. Otherwise, solutions are developed which can provide priority to transit without severe negative impacts on other traffic flows.

Zurich Transit identifies areas and delay for their vehicles. Trip times on a particular line are calculated based on ideal conditions. Data is then collected on the actual transit time and the delays encountered. The difference between theoretical and actual is defined as waiting/delay time.

The Zurich policy is to have zero waiting time. Therefore, an average delay of over 10 seconds/intersection is considered a lot in view of their attempt to maintain schedules to a close tolerance. Consequently if transit information can prove there is a delay, the police will try to do whatever they can to reduce or eliminate that delay.

6.5.4 Process of Implementation

The implementation of priority to surface transit vehicles was initiated as a result of the public's negative reaction to the expenditure of funds on subway construction. The objectives for traffic management emanated from that decision with the number one objective being the improvement of public transit.

Decisions on traffic management measures are made by a working group consisting of representation from three areas:

1) Public Transport
2) Police
3) Civil Works

Each of these groups is involved in the implementation of any solution. If there is agreement by this working group, the solution is implemented. If there is no agreement, the decision goes to a working group consisting of political representatives of each of the three groups, plus the Directors of Transit, Police, Planning and Civil Works. This group makes the ultimate choice on options and sets guidelines for implementation. The police department group is responsible for the design of any solution and the civil works group is responsible for its construction. The public transport group enjoys the benefits.

Zurich Transport and the police are very happy with their system. To date, few problems have been encountered. They are currently in the process of updating their computer

equipment one zone at a time. This expenditure for new computer equipment is expected to be 8 M SF and a benefit of 2 M SF/yr. has been estimated. This may be somewhat overestimated since much of the benefit has already been achieved.

The City currently has a budget of 5 M SF/yr. to install equipment at new intersections, develop computer programs for control and maintenance (The Swiss Franc is approximately $1.00 Canadian).

6.6 EVALUATION

6.6.1 Definition of Methodology

Zurich Transport officials and the police were not able to provide a definitive methodology for measuring the benefits of the traffic signal priority measure. In effect, it has been only one element of a series of priority improvements for transit.

Their biggest measure of success is that the system is moving and very little congestion is evident. They have achieved virtually zero waiting for trams and buses. Their transit ridership is the highest in Europe among similar sized cities and rides/capita exceed 450, almost twice that in Stuttgart and Hanover, Germany.

6.6.2 Longer Term Experience

The referendum results some 20 years ago changed the direction of traffic management and control in Zurich. Since that time, the greatest emphasis has been placed on making transit more attractive for the majority of trips. Priority treatment of transit has been implemented gradually with little impact on general traffic.

Transit speeds have been increased by eliminating virtually all delays associated with traffic signals and congestions. Traffic management has focused on short term control, reducing delays at individual congestion points as they arise. The long term strategy is to get as many people to use transit as possible.

6.6.3 Costs

The following is a summary of the cost figures provided:

New Signal Installation • includes all costs associated with the installation of signals, cables, detection, etc.	-	500,000 SF/intersection
Existing Signalized Intersection	-	10,000 to 20,000 SF/intersection
Detectors	-	2,000 SF
On-board Transponder	-	300/400 SF
Annual Maintenance • includes new intersections, computer program maintenance and equipment maintenance	-	5 M SF
Annual Salaries for Police Department in Charge of Signals	-	3 M SF

Note: The Swiss franc is approximately $1.00 Canadian.

6.7 FUTURE PLANS

Zurich police department, in charge of traffic control, plans to continue improving the system and providing priority for transit wherever possible. They are very happy with their system and believe that it is the best solution for their particular environment.

They recognize the traffic environment as dynamic, requiring consistent monitoring and adjustment to keep traffic moving. They are currently upgrading their computer system, converting one zone (there are seven) at a time. During this changeover, computer programs are being enhanced to allow more effective control of movement on the street.

6.8 SUMMARY OF INSTALLATION

The Zurich installation of priority at traffic signals appears to be the best of those viewed on the field trip. The virtual elimination of delay for transit vehicles at signalized intersections is truly remarkable.

Innovative solutions have been applied to provide priority for transit vehicles at a variety of locations where delay was occurring. Bus lanes, bus only turns, and queue jumpers have been combined with signal priority for transit vehicles to reduce delay.

6.9 OBSERVATIONS

A tour of the Zurich system provided a view of the various strategies used to give priority to transit vehicles. It is quite exciting to ride a tram and see the traffic signal turn green in front of you at every intersection. Observation at key locations indicated zero delay for trams and virtually no delay for buses at the same location (buses are given second priority to trams). The use of a combined reserved right-of-way for both trams and buses seems to work well. Buses weave from reserved areas to the curb without the need for traffic control.

The two-way bus lane controlled by signals at each end of the section indicates the novel solutions that can be applied where there are competing road requirements.

It appears that Zurich's policy of keeping all traffic moving, by using various solutions at key congestion locations, has been a success. Although priority is given to transit, auto traffic does not appear to be significantly delayed. In effect, the parallel private auto traffic benefits in many areas where transit is given priority at signalized intersections. No severe traffic congestion was observed where private traffic had to wait an unacceptable period of time.

7. NANCY (FRANCE) CASE STUDY

7.1 INTRODUCTION

Nancy is a smaller sized city with a population of approximately 100,000. The service area includes 18 other smaller communities with an additional 150,000 population. The urban service area is approximately 128 km^2. Additional service is provided to outlying suburban areas.

The Nancy area is generally flat in nature. The road system is basically a grid with some radial routes extending to the outer municipalities. The transit route system has developed on this combination grid/radial network.

During the field trip, the following people were interviewed at the transit authority and traffic authority.

Transit

Mr. Moselle
Director, Nancy
CGFTE*
11, Avenue de Boufflers
BP 3683
54097 Nancy, Cedex

Mr. Ferry
Manager - Professional Training

Mr. Lalisse
Manager - Human Resources

Mr. Degoutin
Manager - Vehicle Maintenance

Traffic Control

Mr. Ladaigue

*CGFTE stands for Compagnie Générale Française de Transports et d'Entreprises.

7.2 TRANSIT SYSTEM

7.2.1 Organization

The CGFTE is a private company which operates transit service in approximately 40 cities around the world but mostly in France. The Nancy operation is one of these cities. It is, therefore, a private operation contracted by the City of Nancy without competition. A new contract was recently signed (1992) with CGFTE for the next seven years.

The company provides the operation for a fixed budget (155 M FF.) within which they can do what they want within the funding limit. The community contribution is fixed (approximately 70 M FF.). A revision formula is provided based on indices including such things as fuel prices and customer demand. The District of Nancy pays for all new projects, such as fare equipment, and owns all property and facilities.

A committee made up of the local politicians and company officials makes all decisions. Proposals for changes are generated by both groups. Such proposals are evaluated and recommendations are made.

Transit is promoted as a viable alternative to the automobile. Staff are trained as professionals and drivers obtain a diploma from the Ministry of Works. This process, started in Nancy, is now a national program. The CGFTE philosophy is that each employee is respected for their individual contribution to the company.

The Nancy service area covers approximately 128 km covering Nancy itself and 18 smaller communities. Nancy has a population of 100,000 while the 18 suburban municipalities have between 150,000 and 200,000 people. Apparently, suburban population is declining as people move into the larger cities.

7.2.2 Key Statistics

1991	Buses (Artic)		Trolleys (Artic)		Total (Artic)	
	Urban	Suburban	Urban	Suburban	Urban	Suburban
Vehicles	134 (34)	27 (13)	48 (48)	-	182 (82)	27 (13)
Kms Operated	448 M	.97 M	2.15 M	-	663 M	.97 M
Staff					535	67
Route Kms.					215	61

7.2.3 System Operation

Transit service in Nancy is provided by a network of bus and dual mode trolley coach routes. The dual-made trolley coaches are able to operate off-wire where required. About 1/3 of the trolley coach route system is not electrified. While the majority of service is provided within the urban areas, nearly 1.0 M km of service is operated in the surrounding suburban areas. The route structure is a combination grid/radial system.

7.2.4 Automatic Vehicle Location

The Nancy AVL system is based on the use of beacons at the ends of the line, wheel revolution measurement and radio communication. They believe that they were the first in the world to integrate the AVL system to the traffic control system and provide priority for transit vehicles.

The AVL system generally updates the position of each bus every 30 seconds. Besides the use of beacons and wheel revolutions, the system updates locations based on key bus stop and door openings. Their accuracy is $\pm$ 10 metres.

7.3 TRAFFIC CONTROL

7.3.1 Organization

The traffic signal system is operated as a city department. This department is responsible for all aspects of the traffic control systems including design, installation, operation and maintenance. The transit company has a good relationship with traffic staff and, in fact, the traffic control operation and AVL system monitoring are located in the same room. In this way the two can work together to ensure the minimization of delays for all travellers. The traffic department is also responsible for locating and installing bus stops.

With regard to transit priority, the Traffic Department of the City installs the priority treatment and pays all costs associated with it. The outlying municipalities have no role in these areas.

7.3.2 Traffic Control Methods

There are approximately 350 traffic signals within the Nancy central area and the outlying municipalities. Within the central area, the traffic control system contains about 190 signals

under a central UTC system. The UTC system employs 60 loops to monitor traffic flow. The philosophy is to minimize traffic delays by providing priority for the heaviest traffic flows:

Three different cycle lengths are employed:

peak	-	90 secs.
general off-peak	-	75 secs.
night	-	55 secs.

The UTC system consists of 1 large zone. Up to 10 different plans can be instituted depending on the particular conditions. They intend to update the system in 2-3 years to include all 350 intersections within the UTC.

The downtown core area operates with a series of one-way streets. Two-way streets are more prevalent in the outer areas.

7.4 PUBLIC TRANSIT PRIORITY

7.4.1 Philosophy

The transit philosophy is to prepare for the future by anticipating problems that will be encountered and developing solutions for these problems. Such problems may be traffic, technical or training related. In the traffic area, the philosophy is that transit needs priority. This is supported by the transit company and the politicians.

7.4.2 Existing Priority Measures

The following priority measures are currently used in Nancy.

Reserved Bus Lanes

There are currently over 22 reserved bus lane locations. These lanes total about 13 km in length including a portion of bus only streets in the downtown area. Taxis and bicycles are allowed to use the bus lanes.

The hours of operation are generally from 5:30 a.m. to 9:30 p.m. The downtown transit only section, which is in effect at all times, has a maximum of 50 buses/hr. during peak operation.

Bus Only Streets

In the downtown area, there are a combination of streets totalling 2.5 km that are reserved for buses and taxis only. Approximately 50 buses/hr. use the main downtown bus only street.

Bus Only Turns

There are a number of bus only turns with separate lanes for access to the bus only streets. Priority treatment is given at a number of locations by allowing buses only to turn.

Transit Priority at Signalized Intersections

Priority for transit vehicles is possible at 80 (out of 190) of the traffic signals in the central area and at 42 locations under isolated control outside of the central area.

7.5 TRAFFIC SIGNAL PRIORITY FOR TRANSIT VEHICLES

7.5.1 Mechanism for Signal Priority

UTC System

When a transit vehicle is late, as determined by the AVL system, and is in the approach zone of an intersection, the transit control centre computer contacts the traffic control computer requesting priority for the vehicle and transmits a message consisting of location, intersection number, distance of vehicle from intersection, direction of approach, etc. As the bus continues, the bus is interrogated more frequently to determine that it is proceeding to the intersection. Based on the progression of the signal cycle, the priority strategy is selected and provided. At this time there is no method used to determine that the priority provision has been used.

Isolated Locations

At isolated signal locations, the transit control centre computer, using AVL data, informs the transit vehicle that it is in the approach zone of a signalized intersection. The transit vehicle microprocessor sends a message by radio to the local signal controller, which is equipped with a radio receiver, requesting priority. Depending on the conditions and signal phasing, the

appropriate priority strategy is selected and provided. A second message is sent to the signal controller when the vehicle passes through the intersection.

7.5.2 Priority Strategies Used

Both green extension and red truncation are used to reduce bus delays. The strategies are in place 24 hours/day but are only provided if the bus is late. Priority can be provided on each arm of an intersection but is provided on a first-come/first-served basis.

For intersections where priority is used, farside stops are preferred. A distance of at least 100 m to the next priority location is preferable. Locations where nearside stops are used do not get priority treatment.

Green extension timing is provided in steps from 5 to 20 seconds. Downtown locations are generally 5 seconds while the outer areas can receive more time. For red truncation, a maximum of 15 seconds is taken from the red phase. It could be less in the downtown area.

The strategy used for bus priority depends on the location and traffic conditions encountered. There is no cut-off mechanism after the bus has passed through the intersection.

Where priority is provided in association with a bus lane, other traffic will have the same green time. The bus, however, determines when the green is provided. At locations where a bus lane ends, the bus is given some advance green time to get through a congested area first.

7.5.3 Criteria for Site Selection

There are no set criteria for the installation of the transit priority at signalized intersections. Those sites selected were based on:

- importance of routes (higher frequency and passengers)
- frequency
- relationship to UTC area

The majority of sites selected were under the UTC control. In addition, 42 isolated intersections outside of the central area have been equipped to provide priority for transit vehicles.

7.5.4 Process of Implementation

At the time that Nancy was considering the provision of priority for transit vehicles at signalized intersections, nothing else was available in France. The officials viewed other systems and strategies being used in other European cities. A feasibility study was undertaken including a cost/benefit analysis to consider all elements, i.e. signal control, AVL, priority equipment, etc.

The results of the study were positive and the transit company proceeded in association with the City's traffic control department.

7.6 EVALUATION

The evaluation of transit priority at signalized intersections was undertaken in 1985 following a major investment of some 350M FF. (approximately CDN $91 Million) between 1980 and 1985 in what was called "Operation Trolleybus". This program consisted of the introduction of 48 new dual-made articulated trolleybuses to be operated on three routes, the upgrading of the UTC system, the introduction of an AVL system, the linkage of UTC and AVL systems to provide priority for transit vehicles at signalized intersections, a number of traffic management measures including reserved bus lanes and bus only streets in the Nancy city centre, and other measures such as upgraded bus stops and bus shelters.

The criteria used to evaluate the effectiveness of the package of improvements were:

- increase in overall system speeds.
- reduction in corridor journey times.
- reduction in variability of journey times.

7.6.1 Evaluation Results

It is reported that "Operation Trolleybus" increased the network productivity, measured by kilometres travelled per (driver) hour, by 15 percent. This is made up of approximately:

- 5 percent due to reserved bus lanes;
- 5 percent due to better scheduling as a result of statistical data obtained from AVL; and
- 5 percent due to signal priority for the transit vehicles.

Along a route defined as representative of the network as a whole, 20 of 30 signalized intersections were set up to provide priority for transit. An average reduction of 6.38% of travel time was recorded, when excluding those signalized intersections not providing priority, and an average reduction of 5.34 %, including all signalized intersections.

Reliability also improved as follows:

- Arrivals within 3 minutes of expected time increased from 46 percent without signal priority to 65 percent with signal priority.
- 90 percent of vehicle arrivals were within 6 minutes of expected arrival times with signal priority compared to within 10 minutes without signal priority.

It was also estimated that there was a 2.2 % saving in energy consumption following the implementation of the priority measures.

During discussions with Nancy staff, their biggest concern related to the reduction in transit speeds which is measured on an annual basis. Following implementation of the system of improvements in 1982, speeds gradually increased to a peak in 1987. Since that time, a gradual reduction in speeds has been evident.

Problems with the system have really only been of a general nature. For example, the radio frequency issued was in close conflict with another system in the area. Software problems were encountered, as might be expected, and the system reached capacity very quickly.

7.6.2 Longer Term Experience

As mentioned, there appears to have been a deterioration in bus speeds after the initial improvement. This may, in part, be due to the increase in overall trips/person which have tended to be by car.

7.6.3 Costs

No breakdown of costs was provided.

7.7 FUTURE PLANS

There are plans to update the signal system over the next 2-3 years whereby all of the 350 intersections in the Nancy area can be included under UTC. This will also allow more opportunities for additional signal priority locations to be implemented.

7.8 SUMMARY OF INSTALLATION

The installation of priority for buses at signalized intersections in Nancy appears to be a success. The CGFTE is a progressive company that is moving ahead on many fronts to improve transit operation with the City. With an improved signal system with increased capacity, it is only a matter of time before the number of transit priority installations is increased.

7.9 OBSERVATIONS

Similar to the London situation, it was difficult to specifically observe the provision of priority for transit vehicles due to the philosophy used (i.e. late vehicles only). However, in the downtown area in particular, transit vehicles clearly have the right-of-way.

8. ANGOULEME (FRANCE) CASE STUDY

8.1 INTRODUCTION

Angoulême is a small town in the 'department' of Charente in the west of France, and some 120 km north-east from the City of Bordeaux. It has a population of 50,000 inhabitants and covers an area of 21.5 km^2. Greater Angoulême, which is served by STGA, includes the 12 surrounding communes of Angoulême covering an area of 170 km^2 and has a total population of 100,000 inhabitants.

For the field study, the following people were interviewed:

Mr. Pierre-Jean Vauclin
(now Mr. Lordon)
Manager - Information
Société de Transport du Grand
Angoulême (STGA)
554, Route de Bordeaux
16000 Angoulême
France

Mr. Jose Moreau
Manager - Public Relations

Mr. Marc Bedier
Manager - Tourist Operations

Mr. Jean Michel Mario (unable to attend)
Manager - Traffic Operations

8.2 TRANSIT SYSTEM

8.2.1 Organization

STGA is a public service organization set up some 15 years ago to provide and manage transit services to Greater Angoulême. It functions as an autonomous organization, in that the running of STGA, including employee pay settlements (STGA operates a performance-related pay scheme) and the competitive tendering of contracts. Follow-up negotiations, are undertaken following its own independent guidelines with minimum bureaucratic hurdles.

STGA has an annual budget of 80 M FF. The total revenue of STGA, mainly through the sale of tickets, covers 50% of its budget. Some 65% of the 40MM of subsidies come from tax levied by the District of Grand Angoulême on local businesses, and the rest from the State.

8.2.2 Key Statistics

STGA's operation can be summarized as follows:

Staff	-	220 (of which 120 bus conductors)
Number of routes	-	12
Total Route Length	-	370 km
Fleet Size	-	92 buses (including 3 minibuses)
Annual Passenger Trips (91/92)	-	11 million
Annual Vehicle-km (91/92)	-	4 million

A private bus company, ROBIN, operates on a small part of the network on behalf and in association with STGA. ROBIN buses, painted with STGA's logo, add another 10 buses to STGA's flat of 92.

8.2.3 System Operation

The STGA provides transit service (bus only) within the City of Angoulême and to the 12 surrounding communes which make up Grand Angoulême. There is one small private company (ROBIN) which operates under contract to the STGA, but to all intents and purposes, its service is perceived as part of the STGA.

8.2.4 Automatic Vehicle Location

STGA operates a bus location and management system known as SMAG (Le Systeme de Mesure, d'Analyse et de Gestion) which has been in place since 1985.

The automatic location of buses is achieved by the use of radio link between buses and SMAG's computer via a radio receiver/transmitter. Each bus is interrogated every 20 seconds by the transit control centre computer for information on its identity, its route number, and its position. The computer determines the location of a bus from the following data radio message received - the opening of doors at bus stops whose locations are precisely known, and odometer readings which indicate distance travelled. Correct operation, (i.e. no diversion away from route and door openings at precise points at designated stops) ensures the location of a bus is known to within $\pm$10 metres of its actual position on the road.

AVL enables the determination of the performance of individual buses against a set time-table, and allows the transit operator to take necessary actions. On a day-to-day basis, AVL enables SMAG to inform drivers of whether they are ahead or behind schedule, and in case of significant delay to a bus which is beyond corrective measures by a driver, it enables the transit controller, for example, to decide whether to despatch a bus from the depot to cover for the delayed bus. More strategically, the analyses of day-to-day journeys provide a base for updating bus scheduling on any particular route in order to maintain a reliable service. For passengers, AVL is the tool which enables the SMAG system to provide real-time information (time of arrival of next bus) on visual display units at the Champ de Mars transit centre, and on-board information about the next stop.

8.3 TRAFFIC CONTROL

8.3.1 Organization

Traffic signals are the separate responsibility of the Traffic Signal Control Department of the District of Grand Angoulême. However, since the implementation of signal priority at 41 isolated intersections on the outskirts of the town centre (and SMAG) in 1985, STGA has worked very closely and enjoys an excellent relationship with the Traffic Signal Control Department.

8.3.2 Traffic Control Methods

The 41 intersections which have been operating transit signal priority since 1985, are isolated signalized intersections operating under a set of manually prepared signal plans to cope with varying daily normal traffic conditions.

Intersections in the town centre operate within an urban traffic control (UTC) system which has recently (late June 1993) been replaced, and will provide priority for buses in the future.

8.4 PUBLIC TRANSIT PRIORITY

8.4.1 Philosophy

There is both political will, and eagerness on the part of STGA and the District Traffic Management department to favour transit vehicle movement by means of priority measures. This is demonstrated by the current scheme of extending transit priority to the town centre, and by an ongoing program of traffic management measures called FLUX.

The district of Angoulême is, in fact, in the enviable situation of having been and continues to be able to implement various measures in favour of transit vehicles without much, if any, negative (or positive) response from its inhabitants. Indeed, the town has been successful because there have been ample opportunities to favour transit without causing much inconvenience (delay) to private motorists.

The aim of STGA, and the district, is to create the conditions which would attract private motorists to use public transport, and consequently reduce traffic flow and avoid future potential problems.

8.4.2 Existing Priority Measures

At the time of the visit, Angoulême had in place the following measures:

Reserved Bus Lanes

Angoulême has some 3.8 km of reserved bus lanes. These are essentially located outside of the town centre and are used by emergency vehicles as well. In Angoulême, bus lanes extend right up to the intersections.

Bus Only Streets

There are 2 km of bus only streets, most of which are found in the city centre. Bus only streets are not only signed to indicate their exclusive use but are also equipped with bus gates. These gates are, in effect, ditches or car catchers which allow the buses with their wide wheel base to go through while prohibiting the entry of other vehicles.

8.5 TRAFFIC SIGNAL PRIORITY FOR TRANSIT VEHICLES

8.5.1 Mechanism for Signal Priority

This can be explained as follows:

A central computer at the transit control centre interrogates each bus every 20 seconds in order to locate the position of the bus on its route. The computer also knows the location of every signalized intersection on each route and consequently, it knows, at all times, the next intersection the bus will come across.

A radio receiver/microprocessor unit, installed in close proximity to the traffic signal roadside cabinet, awaits the radio signal call for priority from the bus.

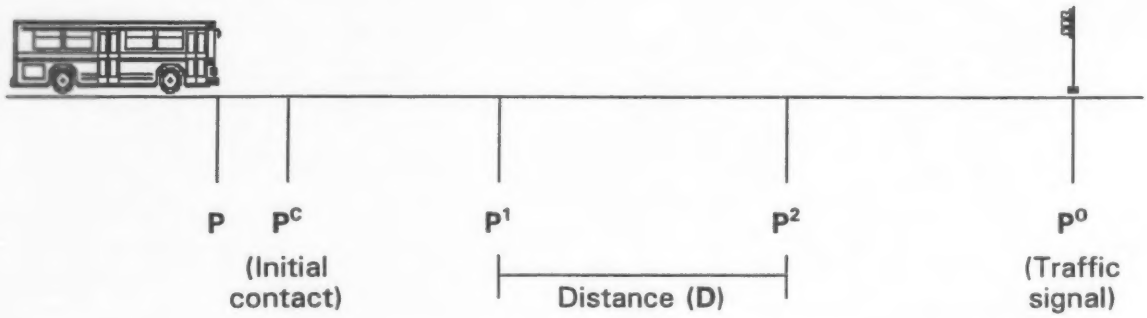

FIGURE 2.1
BUS APPROACH TO INTERSECTION

Figure 2.1 represents the 4 principal stages as the bus approaches an intersection. Point Po is at the traffic signal controller.

i) The bus is at point P. Its position is known by the transit control computer to an accuracy of $\pm$10 m (a necessary condition for optimum operation).

ii) The bus has passed point Pc and is in the approach zone of the intersection. The computer relays to the bus all the parameters that characterize the intersection with respect to its identity and location:

- intersection number;
- approach link number;
- priority allowance or inhibition, and
- distance D = P1 - P2.

Priority inhibition is rare and is usually associated with the case where a bus has been diverted (say, due to an accident/roadworks) and is therefore approaching an intersection which is not on its normal route.

iii) The bus, in possession of this information, measures distance D, and on arrival at point P2, sends a radio message to the roadside unit requesting priority. The distance P2-Po is sufficient to allow the roadside unit to modify the current signal cycle in order to give the green light to the bus when it arrives at the intersection.

iv) The bus is at point Po and crosses the stop-line. It sends a second message to the roadside unit to signal its passage (based on AVL odometer information).

8.5.2 Priority Strategies Used

The roadside unit is interfaced with the intersection signal system. It permanently scrutinizes the operation of the signals and knows, at all times, the current signal phase and for how long it has been operating. Hence, when priority is requested, the unit can act on the sequence of phases in two possible ways:

- **extend the green phase until the arrival of the bus at the intersection, whilst not exceeding a maximum green time; or**
- **speed up the phases (red truncation) in order to give the green phase to the bus before its arrival at the intersection.**

For safety reasons, the system respects set minimum and maximum green times for that intersection. The intersection reverts to the normal cycle once a bus has cleared the intersection.

8.5.3 Criteria for Site Selection

The locations selected for the provision of signal priority were based on a number of factors. Firstly, transit routes at the locations selected were subject to delay at signals. The locations selected were under isolated signal control outside of the central area of Angoulême. These locations were easier to implement as they were not included in the downtown green wave area and therefore would have less of an impact on general traffic.

8.5.4 Process and Implementation

The decision to implement signal priority for transit in Angoulême was engineering-driven but with full political approval and support. Angoulême, in addition, has been on the leading edge nationally for transit AVL and transit priority.

In implementing signal priority at the 41 isolated intersections, 3 technical departments were involved - traffic management, traffic signal and STGA.

The scheme was preceded by the conduct of a feasibility study.

8.6 EVALUATION

8.6.1 Definition of Methodology

In order to statistically assess the efficiency of the signal priority scheme, a study of 16 intersections (out of 41) was undertaken in 1985.

Two types of measures were used to assess each intersection:

i) An analysis of the average waiting time at the red phase and of the standard deviation, with signal priority operating.

ii) A similar analysis, without signal priority in operation.

A sample of 40 $\pm$5 buses was used for each intersection. Each observer at an intersection recorded the number of buses which crossed the stop-line without encountering a red phase, and the time duration between a stop due to a red phase and the departure of the bus across the stop-line.

The X^2 (Chi quare) test was used to demonstrate whether there was, or was not, a significant difference between the "with" and the "without" priority cases.

8.6.2 Evaluation Results

Table 5 is a summary of the results of the assessment of the 16 intersections. Globally, the throughput of buses, during the green phase, has increased from 52.5% to 79.1% with the help of signal priority. Consequently, the reliability of bus services as expressed by standard deviation of waiting times at red phases, has also improved, decreasing from 15.4% to 8.05%.

It is generally agreed that a saving of 10 seconds per bus per intersection has been achieved.

No negative effect has been observed for cross traffic. Indeed, since bus routes are on the principal roads for 75 percent of the intersections studied, other traffic would have also benefited by signal priority.

8.6.3 Long Term Experience

Of the 16 intersections studied, 2 showed negative effects of signal priority with regard to throughput of buses during green phases - intersections 3 and 7. These are explained as follows:

TABLE 5

EFFECTIVENESS OF TRANSIT PRIORITY TRAFFIC CONTROL SYSTEMS IN ANGOULEME

SUMMARY RESULTS FOR THE 16 JUNCTIONS

Intersection Number	With Bus Priority					Without Bus Priority				
	N	K	TM	ET%	P%	N	K	TM	ET%	P%
1	40	35	4.8	40.4	87.5	38	31	18.8	76.4	81.5
2	41	31	13.5	37.9	75.6	40	20	15.7	44.8	50.0
3	41	33	13.3	41.7	80.5	40	32	11.8	35.8	80.0
4	41	30	11.1	59.4	73.2	41	18	16.6	52.7	44.0
5	42	35	8.2	68.0	83.0	41	25	10.0	55.3	61.0
6	49	32	12.7	61.2	65.0	47	28	15.0	38.5	59.0
7	32	19	7.15	64.0	59.0	37	25	9.6	34.6	67.0
13	47	37	17.1	65.0	78.7	48	23	14.6	52.3	47.9
14	49	45	20.2	29.5	91.8	48	30	12.4	45.2	62.5
15	45	38	10.0	80.2	84.4	45	18	12.7	59.6	40.0
16	49	43	11.0	50.8	87.7	46	29	11.0	83.9	63.0
18	58	45	9.4	63.8	79.0	60	22	11.3	52.3	36.0
25	38	29	23.7	77.3	76.3	48	19	21.6	55.4	39.6
26	44	36	19.3	49.8	81.8	50	23	23.4	50.0	46.0
27	43	36	17.8	78.9	83.7	44	14	19.3	50.3	31.8
28	24	19	41.6	37.0	79.0	23	7	23.2	46.5	30.4

N = Total number of buses
K = Number of buses which crossed during a green phase
TM = Average waiting time at a red phase for a bus (sec.)
ET = Standard deviation (as % of TM)
P = Percentage of buses which crossed during a green phase

- Intersection 3 has already high throughput of buses (80% of total buses) during green phases without signal priority, and thus represented a case where significant improvements were limited, and

- Intersection 7 is located at the town centre, and it was difficult to obtain sufficient approach distance to the intersection (point P2 in Figure 1) to enable the priority strategy to work efficiently.

8.6.4 Criteria for Installation

Following the assessment of the 16 intersections, it was concluded that it would be advisable to study each intersection for their throughput of transit vehicles during green phases before implementing signal priority at an intersection. If the throughput is near or exceeds 80 percent, it is not recommended to provide signal priority at that intersection.

From the summary of Table 6, it is suggested that signal priority is not recommended:

- For intersections operating cycles of 2 phases, where the throughput level reaches 80 percent and 60 percent at the outskirts and in the town centre respectively.

- For intersections, operating more than 2 phases, where the throughput level is at 65 percent.

8.6.5 Costs

The cost of implementing signal priority at the 41 intersections is difficult to estimate since the passenger information and management system, SMAG, and signal priority are closely linked. It is likely that signal priority would not have been implemented without SMAG. The total cost of implementing SMAG and signal priority was 10 M FF in 1985. (Note: The French Franc is approximately $.26 Canadian.)

8.7 FUTURE PLANS

A new on-line UTC system, controlling 24 intersections, known as MARGOT (Modèle Angoumoisin de Régulation et de Gestion Optimisée du traffic) has been installed in Angoulême town centre this year. MARGOT replaces an older traffic signal control system. Unlike the existing system where priority is given every time it is requested by a bus, the new system will provide priority only to late buses (>1 min.) and communication will be via SMAG to MARGOT.

The primary concern of the MARGOT system will be to regulate the movement of all traffic in a smooth way. As such, priority will only be given to late buses as and when MARGOT can accommodate such a request from SMAG without causing 'undue perturbations' throughout the network it controls.

It is anticipated that benefits to buses will be less when compared to isolated intersections, due to the constraints under which MARGOT operates.

TABLE 6

EFFECTIVENESS OF TRANSIT PRIORITY TRAFFIC CONTROL SYSTEMS IN ANGOULEME

CRITERIA FOR PRIORITY IMPLEMENTATION

Intersection Number	% of Bus Throughput During Green		Number of Signal Phases
	With Priority	Without Priority	
1	87.5	81.5	2
3	80.5	80.0	
4	73.2	44.0	
5	83.0	61.0	
14	91.8	67.5	
15	84.4	40.0	
18	79.0	36.0	
6	65.0	59.0	2 (Town centre)
7	59.0	67.0	
2	75.6	50.0	3
13	78.7	47.9	
16	87.7	63.0	
26	81.0	46.0	
27	83.0	32.0	
25	76.3	39.6	4

A report on the implementation of priority within the MARGOT system will be available later this year.

8.8 SUMMARY OF INSTALLATION

The implementation of bus priority at signalized intersections in Angoulême has been, and still is very successful primarily due to 3 reasons, namely:

i) The scheme had political as well as institutional support in a bid to propel Angoulême, the state-of-the-art transit city, forward as the first French town to provide a technologically advanced and efficient public transport service.

ii) The suburban characteristics and location of the intersections meant that the opportunities to provide priority were greater and caused less disruption to other traffic than would have been possible in the town centre.

iii) Angoulême started to implement priority measures prior to the development of traffic problems, thereby finding and implementing solutions to 'anticipated future problems'.

8.9 OBSERVATIONS

A brief guided tour of the network included the bus terminus at Champ de Mars, where bus waiting times are displayed to passengers on video monitor screens, the operation of bus signals at intersections with reserved bus lanes, and bus-only streets that are equipped to prohibit the entry and use by other vehicles by the mechanism of a 'bus gate' which allows a bus, with its wide wheel base, through, but not a smaller vehicle.

It was difficult to observe the operation of bus priority at signalized intersections but it was clear that buses which did not manage to cross an intersection on the first attempt did not have long to wait.

A visit was also paid to the new traffic control centre which will house MARGOT and where preparations were underway to accommodate MARGOT's computers and wall display.

9. CONCLUSIONS FROM FIVE CASE STUDIES

General Conclusions

- Much more emphasis is placed on transit in the European community. This emphasis, as might be expected, varies by country and municipality.
- There was a political will in the cities visited to reduce transit delays and encourage transit ridership.

Experience to Date

- All the cities visited had been working on transit priority measures for some time. Signal priority for transit vehicles may have been the last element investigated.
- All the cities have experienced good results from the signal priority treatment.
- Expansion of the system is planned in each case.
- No installations were a failure, although adjustments were made in some locations to reduce unacceptable negative impacts on other vehicles.

Warrants for Implementation

The following factors were considered by the transit systems in considering transit priority at signalized intersections:

- Lost time due to signal delays.
- Impact of schedule delay on schedule regularity.
- Impact of schedule delay on average schedule deviations.
- Passenger delays.
- Impact of signal delay on operating costs.
- Frequency of service provided.
- Ease of implementation in relation to traffic control.

Effectiveness/Benefits

The following benefits provided a measure of effectiveness for the installations:

- The average reduction in signal delay per intersection appears to be about 10 seconds.
- In Zurich, signal delay has been totally eliminated 99% of the time.
- The cost saving benefits of the system pay for the system over 1-2 years.
- Passenger delay is reduced.
- Transit vehicles are better able to maintain published schedules on a regular basis.

Associated Issues

- Depending on the system used, co-ordination of downtown signals can be maintained through communication or a computer algorithm. The impact of not doing this is unclear.
- Minimum pedestrian walking times are provided based on 1.2 m/sec. walking speed.

Stop Locations

- The accommodation of nearside/farside stop locations varied from city to city. In Zurich's case, the wealth of information collected has allowed them to accommodate any stop location into their programs. In London, the strategy is to reduce delay, not eliminate it, and the stop location generally does not affect the result. However, the policy is to move stops farside or back from the intersection. In the French cities, farside stops are preferred for priority treatment and nearside stops do not get priority.

Installation Conditions

- Generally it appeared that where full priority was provided, the headway on the services affected was 6 min. or greater. However, there were areas where several lines merged (headways 1-1/2 minutes) and full priority was provided. In London, where combined service on a link may exceed the 6

min. figure (40-50 buses/hr.) the policy is to reduce delay but not provide full priority.

- The European approach has been to install the transit priority strategy on whole lines or in particular areas rather than at individual locations.

- Initial installations have generally been in suburban areas. However, in 2 out of 5 of the cities visited, priority was available at intersections in the downtown.

- Traffic volumes, number of cross routes and intersection configuration did not seem to make a difference to the installation.

- The only location specifically identified where priority could not be effectively provided included 5 or 6 routes and heavy vehicular volumes.

- In areas of restricted width, transit vehicles were provided a headstart on private vehicles.

Summary of Approach

Table 7 summarizes the approach of the cities visited. Below is a discussion of the individual elements considered.

TABLE 7

TRANSIT PRIORITY TRAFFIC CONTROL SYSTEMS

SUMMARY OF EXPERIENCE FROM FIVE EUROPEAN CASE STUDIES

Elements/Cities	London	Stuttgart	Zurich	Nancy	Angouleme
Traffic Control System					
Central Control	x	x	x		
Isolated				x	x
UTC System	x			x	Future
Associated Priority Facilities					
With Bus Lanes	x		x	x	
Without Bus Lanes	x	x	x	x	x
Relation to AVL System					
Combined with AVL		Future		x	x
Not Combined with AVL	x	x	x		
Strategies Employed					
Green Extension	x	x	x	x	x
Red Truncation	x	x	x	x	x
Red Interruption		x	x		
24-hr. Priority	x	x	x	x	x
Priority Cut-Off		x	x	x	x
Compensation Following Priority					
Green Extension		x	x		
Red Truncation	x				
Conditions of Priority					
Reduced Delay	x				
Full Priority		x	x		x
Late Buses Only				x	Future
Technology Employed					
Looped	x	x	x		
Beacons		x			
Radio		x		x	x
Selection Procedure					
Individual Intersection Analysis			x	x	x
Full Line Implementation		x	x		
System Implementation					
Area Implementation	x		x		

Traffic Control Systems

There does not appear to be one system that suits the application of signal priority for transit vehicles. In fact, there were differing opinions regarding the delays associated with routing a priority request through a central control facility. The majority of cities visited started their priority program at isolated intersections. Consideration is being given, however, to expanding the system to parts of the City under urban traffic control (UTC). In London, although they have initially implemented transit priority in suburban areas with lower traffic volumes and isolated control, they are reviewing opportunities to incorporate priority strategies in areas under UTC SCOOT Control.

Associated Priority Facilities

It was obvious from the observations that various strategies can be employed with or without reserved bus lanes. The use of the combined elements perhaps allows greater opportunity to reduce transit delay but is not necessary under all conditions.

Strategies Employed

All cities visited used both green extension and red truncation strategies to provide priority to transit vehicles. From observation, it appeared that Zurich was also able to effectively use red interruption in some cases.

All systems visited provided priority on a full time 24-hour basis.

A cut-off facility, activated when the transit vehicle passes through the intersection, was employed in 4 out of 5 case study sites.

Compensation Following Priority

The general consensus in this area is to provide some compensation to the cross street following the priority initiation. In London, this is provided after a red truncation call only.

Conditions of Priority

The approach to when priority should be provided varied in the cities visited. As mentioned under the case study, Zurich leads the cities visited, in that full priority is provided for transit vehicles 95% of the time, based on their vehicle priority order (trains first, buses second). London has employed the philosophy of reducing delay for all buses while the French cities are leaning towards priority for late vehicles only.

Technology Employed

The technology employed for detection of a vehicle and transmission of the request through the signal equipment varied throughout the cities visited. There did not appear to be any strong evidence that one method should be favoured over another. The difference between them related more to the philosophy of detection, placement of loops and therefore, cost than anything else. The French cities combined their signal priority system with their AVL system and therefore had no problems with loops. Stuttgart felt that the loop costs were excessive and were looking at the use of AVL type equipment and radio communication as an alternative. Zurich, on the other hand, was very happy with the performance of their loop detection system.

Selection Procedure

The selection and implementation procedures also varied by city from individual locations to full system commitment where possible. Zurich has the commitment to provide priority for transit throughout the system. They are to the point now where they review individual locations if problems arise. The French cities review locations on an individual basis, while Stuttgart has selected full lines for implementation and London has selected areas.

Of the cities visited, Zurich appears to be the furthest advanced in employing not only signal priority for transit vehicles, but other priority measures for ensuring transit receives priority over the private automobile. Their "zero wait" philosophy for transit vehicles seems to provide the priority required, without significant negative impacts on other traffic. Much of their success can probably be attributed to the fact that

they have been working at it for nearly 20 years. A wealth of data has been collected and they have developed sophisticated computer programs that control all traffic.

Differences from the North American/Canadian Environment

The following observations are made from the discussions held with officials in the cities visited and a review of operation in this field.

- there seems to be a higher commitment to transit.
- greater emphasis is given to the movement of transit vehicles at the expense of other traffic.
- there is a good working relationship between the transit and traffic officials.
- there is a commitment to trying various strategies to improve overall traffic flow.

10. IMPLEMENTATION OF TRANSIT PRIORITY TRAFFIC CONTROL SYSTEMS IN CANADIAN CITIES

From the review of the case study cities, it is clear that significant benefits have been produced from the implementation of priority for transit vehicles at signalized intersections. The purpose of this Chapter is to discuss issues related to the implementation in Canadian cities and to provide guidance to transit system managers and traffic engineers in pursuing such opportunities.

10.1 CANADIAN TRAFFIC CONTROL SYSTEMS

Technical

Currently Canadian cities operate the following types of traffic control systems:

Isolated Control

This type of traffic control operates in isolation with no control interaction with adjacent intersections. Local detection of vehicles can modify the timing allocation in accordance with preset logic that can be initiated through software or hardware logic. The majority of equipment is standardized in accordance with the North American Manufacturers Association (NAMA) specifications. All solid state equipment has the ability to provide signal modification based on detector input (preempt functions). Older electro-mechanical equipment can be modified with machine logic modules to perform similar function, although the sophistication afforded is much less than for solid state equipment.

Interconnected Systems

A variety of interconnected traffic control systems are in operation throughout Canada. These systems consist of local control logic interconnected with communication lines to supervisory or monitoring logic. Specific timing plans are implemented by ensuring that each local control unit implements specific timing instructions. The supervisory logic is contained in software or hardware logic at the supervisory site. State of the art systems also utilize measured vehicle demand to develop and modify controls in real time. The demand measurement includes detection equipment which can discriminate between transit and other vehicles.

Fixed Time Systems

These systems are capable of executing local signal modification based on local detection of a transit vehicle usually through the execution of a special function in the local control equipment. As well, specific timing plan modifications that would provide transit priority can be initiated. The most common form of transit priority operated in these fixed time systems is the operation of timing plans that have been developed to ensure transit preference.

Traffic Responsive Systems

Traffic responsive systems utilize measured traffic demand data to develop or modify traffic plans in a real time setting. These systems are extremely complex and, therefore, the application of transit priority in such systems has not been utilized extensively in Canadian applications. It is certainly possible to locate detection equipment such that transit requirements can be dealt with in a preferential manner. As well, local initiation of preemption is achievable.

Institutional

The relationship between traffic and transit authorities varies across the country. Generally, traffic control rests within a department of a city or regional municipality. Transit, on the other hand, could have one of three relationships as follows:

a) Separate Commission or Board

In this scenario, transit is organized as a separate entity from the City departments, reporting directly to Council. Decisions are generally made by the Board within a set of specified responsibilities. Large financial items are usually referred to the municipal Council for approval and funding.

This scenario results in a working relationship between traffic and transit officials without a common set of goals and objectives. Each department is working somewhat in isolation of the other with only nominal interaction in common areas.

b) Separate Department within City

This scenario provides somewhat of a closer relationship as the departments are working together and have the common goals of the City's transportation plan to follow. The provision of service by a private operator could fit into this scenario.

Within this scenario, department rivalry is still possible as funds are limited and demand for projects is great.

c) Single Transportation Department

This scenario could be a public works or transportation department which has the responsibility for traffic and transit issues. As departmental responsibility rests with one person, there is more likely to be a more harmonious relationship and direction towards the achievement of common goals and objectives. Within the department, officials are likely to be working more closely and share the desire to solve problems. There can still be competition for funds but leadership should prevail in setting priority for the achievement of goals.

10.2 APPLICABILITY TO CANADIAN CONTEXT

On the face of it, the direct transfer of European experience to the Canadian context should be possible. However, there are a variety of factors that must be considered if the success of transit priority at signalized intersections is to be matched in Canada.

Political Viability

A key to the success in European cities appears to be that they have realized sooner than North American cities that the car cannot solve the transportation problems over the long term. Priority for transit is not only a technical priority for the transit companies but also a city priority supported strongly by the political representatives. In the cities visited, this support has resulted in a variety of priority measures for transit to speed up service and to improve regularity.

The various city agencies responsible for traffic and transit realize that they have to work together to get the best results. This does not mean that everyone is against the car. In fact, in some cities the number of car trips is increasing substantially more than other trips. However, there is an awareness that "moving people" is the problem and transit provides a far more efficient solution than the private car.

Opportunities for the provision of priority for transit, while they may start at the management level, are generally supported at the political level. If agreement between traffic and transit officials cannot be reached at the lower levels, the decision is made at the political level. From

that point on, everyone is expected to work towards realization of the goals set by the politicians. The result of this process have generally weighed in favour of transit.

Effectiveness

While there appears to be a lack of specific warrants or guidelines from the European cities visited, there was a strong desire to reduce transit delay. The results of the evaluation tests indicate that the institution of priority for transit vehicles at signalized intersections has indeed reduced delay by about 10 secs./vehicle/intersection.

The effectiveness of the priority strategy has been measured under a variety of conditions and using a variety of technical approaches.

Benefits

The benefits for transit in the provision of signal priority for transit are numerous and it is believed they can be compared directly to the desires of Canadian transit properties.

These benefits can be summarized as follows:

- there is a savings in round trip travel time;
- this savings results in operational cost savings associated with a reduction in vehicle requirements;
- the reduced travel time is a positive factor in attracting ridership;
- there is an increased regularity to the service, in that schedules are maintained more closely and deviations are more regular;
- there is minimal overall impact on other vehicles;
- the systems have been implemented with little complaint from the public.

Costs

The cost of the system has been accepted as reasonable by all the cities visited. This is evident by the fact that each city is actively pursuing expansion of this priority treatment to more locations on the system.

The actual costs of implementation depend on the technology chosen for detection, communication and signal control. Some of the systems have implemented a number of improvements at the same time as signal priority and thus it is difficult to split out items separately.

Isolated signal preemption is quite cheap and depends on the communication strategy to the signal controller and the need for greater sophistication within the controller itself. Each application will have to be reviewed on its own merits as costs would undoubtedly decrease as the system is expanded.

Technical Feasibility

From the observations in the cities visited, it is obviously feasible to install transit priority at signalized intersections under a variety of conditions. The technical sophistication of the hardware required relates directly to amount of information to be analyzed and the type of priority strategies to be implemented.

The hardware required for transit priority at signalized intersections can basically be acquired off the shelf. The greatest decision to be made will be how buses will be detected and how the information will be communicated to the signal controller. The combination of transit signal priority with AVL has been used in some cities while not in others. If it is combined, it simplifies some of the decisions to be made regarding communication. Where it has not been combined, the communication from the detector to this signal controller has been either by hard wire or radio. This selection depends on local conditions.

Institutional Obstacles

The cities visited indicated that there was a good working relationship between traffic and transit authorities. It was mentioned earlier that in Europe, there appears to have been the realization that the private car cannot solve future transportation problems. There is a far greater emphasis on transit and an attempt is being made to make transit travel as attractive as possible. This has resulted in far grater priority being given to transit with regards to dedicated street space and reduction of delays.

Within Canada, some traffic engineers fail to recognize the importance of good transit service in reducing their own problems. Therefore, there is a reluctance to provide priority to transit vehicles when they believe it will be at the expense of private vehicle users. A key element of introducing more priority for transit will be to show that this perception is not the reality. The objective is to keep all traffic moving. Transit can contribute to this objective by attracting more

passengers out of private vehicles. However, traffic engineers must accept that fact and promote transit wherever possible.

Obviously, transit priority at signalized intersections cannot be implemented without the co-operation of the traffic engineering authorities. Also, it is likely that priority will not be possible at all signalized intersections due to traffic volumes or hardware constraints. The two groups will have to work closely together in defining equipment requirements, hardware configurations and signal algorithms.

It is interesting to note that in many instances, transit priority is implemented first at suburban intersections with isolated control, rather than at high volume downtown locations. This is somewhat counter-intuitive but has two advantages: it allows basic technical issues to be resolved in a less critical environment, and enables better communications and trust between the representatives of the transit and traffic engineering departments through their joint experience.

10.3 SUMMARY

The investigation of transit priority at signalized intersections in European cities confirms that such a strategy could be implemented in Canadian cities. The benefits to transit would be directly proportional to the current problems/delays being encountered by transit vehicles.

Obviously, small municipalities with moderate traffic conditions and flow traffic signals would gain less benefit although even small implementations such as in Charlotte, NC, can be sometimes valuable. However, experience in medium to large cities with heavier traffic volumes and a significant number of traffic signals indicates that there are significant benefits to be gained.

The following summarizes the technical conclusions for transit priority at signalized intersections in the Canadian environment.

Priority Strategies

Green extension and red truncation are the two most commonly used and effective strategies. These can be supplemented with red interruption or cycle manipulation and compensation, depending on the sophistication of the hardware and data availability.

Detection Hardware

The detection hardware options are split between loops in the road with transponders on the buses, or loops and a vehicle profile identifier, and various beacons (microwave or infrared) with transmitters/receivers on the buses. Hardware selection depends on local conditions in the city with relation to the reliability and life of in-pavement detectors. The experience by European cities has not provided a clear choice in this matter.

Signal Control

Transit priority at signalized intersections can be implemented on any of the signal systems currently used in Canada. However, the solid state controllers provide greater opportunity for implementing various strategies and more complicated algorithms for traffic control.

The use of a central traffic control facility is not necessary. However, depending on the speed of detection/communication, it could allow the best strategy to be implemented, based on an analysis of private vehicle flow as well.

Integration with Automatic Vehicle Location (AVL)

It is not necessary to combine transit signal priority with an automatic vehicle location system. However, if both systems are contemplated, the hardware requirements and data manipulation could be combined to reduce costs. This has been the experience in the two French cities visited. The radio involved can be used to transmit data to the AVL control centre, as well as to the signal controller unit.

Optional Equipment (Black Box)

Depending on the level of sophistication desired in implementing and operating the transit priority at signalized intersections, additional on-board equipment can be added. This equipment collects data along the route regarding stops, passenger demand, delays, speeds, etc. This information can be used separately or in association with the transit priority system to determine the best priority strategy. The information can also be used to adjust service to reflect on-street conditions.

10.4 COMMON QUESTIONS

The following is a summary of answers to commonly asked questions regarding transit signal priority.

1) *How is pedestrian safety assured during priority implementation?*

Pedestrian safety is accommodated in a similar manner to North American standards. Minimum crossing time is measured using 1.2 m/sec walking speed from one side to the other or to an island. Based on North America's wider roads, this could reduce the strategies possible or the benefit to transit. However, in areas of higher volumes and wider roads, more sophisticated algorithms could be employed if sufficient information is available prior to the transit vehicle's approach to the intersection.

2) *What volumes have been accommodated at locations employing transit priority?*

Traffic volumes up to 1,200 veh./hr./lane have been observed/accommodated at cross street locations in Europe. Obviously, the level of traffic could dictate the ability to implement a strategy. However, compensation to side street traffic is applied in some cities. In addition, in most cases the parallel traffic flow benefits from the additional green time given the transit vehicle. The traffic algorithm employed must be based on local conditions.

3) *How is downstream co-ordination maintained when transit priority is implemented?*

Depending on the level of sophistication of the system, downstream co-ordination can be maintained. It is possible for the signal controller to be advised that priority has been implemented upstream. Adjustments can be made to the downstream signal not only to accommodate more private traffic but also to provide priority for the arriving transit vehicle.

4) *What are the levels of transit service being accommodated at signalized intersections providing priority?*

In the majority of locations observed in Europe, the one-way headway for transit at the priority locations was 6 minutes. However, at some locations where lines converged, the headway was between 1 and 2 minutes and priority ranged from full right-of-way to reductions of signal delay only where possible.

5) *What warrants were used for the selection of priority locations?*

The development of detailed warrants for the implementation of priority for transit vehicles at the signal intersections varies depending on the city's philosophy for transit. The general warrants related to delays being encountered by transit. The overall warrants can be summarized as follows:

- significant time (›10 sec/intersection) is lost at signalized intersections;
- schedule reliability is poor and standard deviation from the schedule is irregular;
- transit throughput during the green phase is poor;
- passenger delay due to delay at signalized intersections is high (i.e. frequent service, high passenger loads).

6) *Is it possible to reduce the impact on private vehicles by shutting off the priority green once the transit vehicle has passed through the intersection?*

Depending on the technical hardware selected for the priority scheme, there are a number of ways to detect the passage of the transit vehicle through the intersection and to terminate the priority green of a green extension strategy. The options range from detectors in the road at the intersection, provision of a pre-specified amount of extra green time based after door closing, or a radio signal to the controller triggered by distance measurements at the intersection. This would not apply to the red truncation strategy as the green would continue for private traffic.

7) *What are the most commonly used or best strategies for transit priority at signalized intersections?*

Experience indicates that both green extension and red truncation are the most commonly used strategies. It has been shown that these two strategies can significantly reduce transit delays at signalized intersections. Other options (cycle manipulation) are possible depending on the sophistication of the system and the availability of other traffic data.

8) *What is the cost per intersection for signal priority?*

Obviously, the cost of a transit priority system depends on the hardware selected. The European experience indicated a wide range of costs and it is therefore difficult to provide a clear answer.

As an example, London spent about $1M (1988) for the installation, testing and evaluation of 56 intersections in the SELKENT project. The expansion of the program to 300 more intersections is estimated to cost approximately $7M (1993). Stuttgart spent approximately $1.6M (1991) for a 7-intersection test on a bus route. The proposed installation for 27 additional intersections has been estimated to cost $7M (1993).

From these two examples, it can be seen that there can be a wide differential in the costs.

10.5 GENERAL APPROACH

Based on European and North American experience, the following is an outline of an approach to determine the feasibility of using the transit priority at signalized intersections strategy for a specific community.

- Assess the current level of delay for transit vehicles at signalized intersections in the municipality.
- Discuss opportunities with traffic authorities for improvement.
- Develop a good working relationship with traffic staff.
- Submit a joint report to Municipal Council outlining the problems and opportunities for transit priority at signalized intersections. Request approval for budget to proceed.
- Review experience elsewhere in similar sized municipalities (North America and Europe).
- Select a route or area for a pilot test.

- Review and select appropriate hardware application for local environment.
- Submit a second joint report to Municipal Council outlining costs and benefits of the strategy. Request approval to implement in a trial location/transit route.
- Call for proposals to supply and install equipment.
- Select appropriate contractor and install equipment.
- Commission project.
- Undertake a before and after evaluation of signal delay to transit vehicles.
- Prepare a full evaluation of the costs and benefits of the strategy.
- Assuming a positive benefit/cost ratio over several years, return to Council to request approval for expansion of the strategy throughout the municipality over a period of years.

10.6 POSSIBLE RESEARCH

A significant amount of development and implementation of transit priority at signalized intersections has already taken place in Europe. However, few installations have taken place in Canada.

In order to develop an economic system for both larger and smaller municipalities, it would be appropriate to develop a general system of off the shelf components that could be used in a variety of locations. The development of such a system would reduce costs and make it more attractive to implement the strategy. Such a system has already been developed for standardizing AVL requirements in Ontario. A similar research project could be undertaken for transit priority at signalized intersections to be applied across the country.

A pilot project is currently planned for a suburban bus route in Toronto. It might be valuable if a medium sized municipality could also be the location of a test project. This will require not only initiative by the local municipality, but also co-operation of the appropriate provincial government to fund such a demonstration.

10.7 SUMMARY

This report summarizes the experience with transit priority at signalized intersections in North America and Europe. The European experience indicates that such a strategy provides benefits to transit with only minor impacts to private vehicles. It is believed that the strategy can be transferred directly to the Canadian environment with little adjustment in approach. The key issues in such an application or for any transit priority application in Canada is to get the political support that transit should have priority over the private car and to build more inter-organized cooperation between transit and traffic engineering departments. This appears to be the major difference between North America and Europe. While the attitude may take some time to change, the change must come if municipalities in Canada are to prosper and grow.

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APPENDIX A-1

LIST OF SELECTIVE DETECTION EQUIPMENT SUPPLIERS

APPENDIX A-1

MAINLINE TRAFFIC SIGNAL PRIORITY STUDY PHASE VI
BUS SIGNAL PRIORITY

Suppliers of Selective Detection Systems		Phone/Fax
Detector Systems Inc. 11650 Seaboard Circle Stanton, California U.S.A. 90680 Attention: Mr. Ray Hoag	Phone: Fax:	(714) 895-6366 (714) 895-6145
Econolite Canada Inc. 1650 Midland Avenue Scarborough, Ontario M1P 3C2 Attention: Mr. Peter Keen	Phone: Fax:	(416) 752-4252 (416) 752-6357
Fortran Traffic Systems Ltd. 470 Midwest Road Scarborough, Ontario M1P 4Y5 Attention: Mr. Sandu Zeller	Phone: Fax:	(416) 288-8222 (416) 288-9914
Southdale Integrated Systems Inc. 2838 Highway 7 Norval, Ontario L0P 1K0 Attention: Mr. Brian Southon	Phone: Fax:	(905) 455-9533 (905) 455-2529
Minelec Limited 2170 Dunwin Drive Unit #3 Mississauga, Ontario L5L 5M8 Attention: Ms. Sharon Leslie	Phone: Fax:	(905) 828-1520 (905) 828-1525
Peek Traffic Inc. 1500 N. Washington Blvd. Sarasota, Florida U.S.A. 34236 Attention: Mr. Ian Cardozo	Phone: Fax:	(813) 366-8770 (813) 365-0837
Plan Electric O. 27 Vanley Crescent Downsview, Ontario M3J 2B7 Attention: Mr. Bob Tracy	Phone:	(416) 635-9040
Wiseman Electric Ltd. 40 Alden Road, Unit #10 Markham, Ontario L3R 5H4	Phone:	(416) 479-2384

Suppliers of Selective Detection Systems	Phone/Fax	
Alcatel Canada Inc. 101 Valley Brooke Drive Don Mills, Ontario M3B 3M6	Phone:	(416) 742-3900 Ext. 203
Topping Electronics Ltd. 215 Nantucket Blvd. Scarborough, Ontario M1P 2P2 Attention: Mr. John Klingworth	Phone:	(416) 285-1272
Novax Industries Corporation P.O. Box 40531 Upper Brant Postal Outlet Burlington, Ontario L7P 4W1 Attention: Mr. Frank Rao	Phone:	(905) 336-1816
Tacel Ltd. 79 Sunrise Avenue Toronto, Ontario M4A 1A9 Attention: Mr. Jeff Smart	Phone: Fax:	(905) 750-4646 (416) 750-4649
Mark IV IVHS 6020 Ambler Drive Mississauga, Ontario L4W 2P1 Attention: Mr. Paul Manuel	Phone: Fax:	(905) 624-3025 (905) 624-4572
Disys Inc. 711 Clayson Road Toronto, Ontario M5M 2H4 Attention: Mr. Steve Leger	Phone:	(416) 745-6044
Other Potential Suppliers		
Comstock International Ltd. 25 Adelaide Street East Toronto, Ontario M5C 1Y2 Attention: Mr. Ed Smith	Phone:	(416) 941-9800
General Traffic Equipment Corp. 218 Willow Street Yonkers, New York U.S.A. 10701	Phone:	(914) 965-9292

Source: Toronto Transit Commission

APPENDIX A-2

REVIEW OF TWO ENGLISH REPORTS

1. The Scope for Bus Priorities in London. London Boroughs Association Review. Hurdle, D., October 1990.

2. Bus Selective Detection in Swansea. Collier, S.C., Department of Transport. London, England. 1980.

The Scope for Bus Priorities in London

The paper, published by the London Boroughs Association, advocates the use of bus priority measures to give buses the capability to relieve congestion problems both on the road and rail networks. A number of ways to provide bus priority were discussed. However, only a small section of the paper was devoted to bus priority at signalized intersections. A number of successful projects were mentioned:

- U.K. DoE demonstration project in 1985 in Leicester and Derby reduced delays to buses, and reduced the range of bus journey times by more than half;

- An initial experiment using the transponder/inductive loop technology in the early 1980s at seven intersections in Hounslow by the Traffic Control Systems Unit (TCSU) found that bus journey times through intersections fell by an average of 10 seconds per bus per intersection. Subsequent cost benefit analysis revealed a very high rate of return; and

- Extension of the experiment with 900 buses and 56 intersections equipped with transponders and loops respectively to the Selkent Bus District in south east London showed a 100% rate of return achieved in the first year.

London Transport (LT) and TCSU are now investing 3.5 million pound for the system to operate throughout London with all LT buses fitted by 1993-94. The investment is expected to be recouped in benefits within one year of operation.

Bus Selective Detection in Swansea

(This paper focussed on the before and after survey and evaluation. No explicit description on the technology and priority algorithm was given.)

The project had it origin in 1976 when the West Glamorgan County Council decided to examine the provision of bus priority measures as operational aid for buses. The lack of road space precluded the use of bus lanes. Most of the points of delays were at traffic signals which were on fairly long cycle times but had some reserve capacity. So selective detection for buses was tried out. The project included 16 set of signals and nearly 200 buses fitted with bus units. Subsequent evaluation found that there was a general non-awareness of the change among bus passengers, pedestrians, and other vehicle drivers. Nor have the police had any report which might indicate that an unusual traffic signal sequence, produced by the bus priority, has caused an accident of any kind. The project has been successful in reducing delays to buses in Swansea city centre. A number of points were concluded:

- selective detection may not contribute any bus time savings on all intersections but will contribute to improved consistency in running times;

- the cumulative effects over all the intersections seem to have been approximately the sum of the effects at the individual intersections;

- the average delay to other traffic is very small in the context of travel times to and from Swansea city centre. In the case of the average, it is equivalent to stopping at one pedestrian crossing;

- as many factors are site specific it is important to carefully survey, tune and adjust each installation during the first few months of operation, particularly if the full number of buses using the intersection are not initially fitted or the project is later extended to include a greater number of buses; and

- the scheme has won the approval of the bus crew and management to the extent that revised schedules have been agreed by incorporating the savings.

APPENDIX A-3

SURVEY OF EUROPEAN TRANSIT SYSTEMS

LETTER AND FORM

TPA
CONSULTING TRANSPORTATION
ENGINEERS AND PLANNERS

Transportation Planning Associates
191 Corporation Street Birmingham B4 6RP
Telephone 021-236 6204 Telefax 021-236 4709
Telex 339110 HIGHPT G

Mr Antonio Ardissone
Transporti Torinesi
Corso Turati 19/6
10128 Torino
Italy

Our Ref.

Your Ref.

Date 8 December 1992

Dear Mr Ardissone

SUBJECT: PRIORITY FOR PUBLIC TRANSPORT AT SIGNALISED JUNCTIONS

On behalf of the Canadian Urban Transit Association, Transportation Planning Associates (TPA) is undertaking a review of schemes, in Europe, which give priority to Public Transport at signalised junctions.

We are writing to you as we understand your city has implemented such a scheme and we would greatly appreciate your assistance in completing the enclosed questionnaire.

The enclosed questionnaire has been designed so that minimum effort is needed on the part of respondents to provide us with accurate information. Please use the questionnaire to describe a particular scheme. In case there is more than one signal priority scheme in your city, please enter the information for each scheme on separate copies of the questionnaire. In addition, we would be grateful if you could supply us with any further detailed information in the form of reports or references to reinforce the information provided in the questionnaire(s).

Please could you return the completed questionnaire(s), and if possible any other documentation giving results of 'before and after' studies, to the address below, before the end of January 1993.

If you would like a summary of the results of our questionnaire survey we will be happy to supply a copy to you.

Contd.

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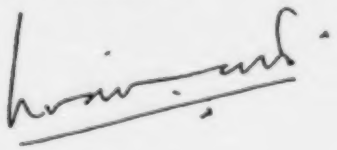
I look forward to hearing from you, and in the meantime thank you for your assistance.

Yours faithfully



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CANADIAN URBAN TRANSIT ASSOCIATION

A STUDY OF PRIORITY FOR PUBLIC TRANSPORT AT SIGNALISED TRAFFIC JUNCTIONS:

QUESTIONNAIRE FOR THE ASSESSMENT OF PRIORITY SCHEMES AT SIGNALISED JUNCTIONS

Name and Address of Contact :

Town/City:

Country :

Population:

Tel No. :

Fax No. :

Tick /Yes = 1
Blank /No = 0

Note: If there is more than one scheme giving priority at signalised junctions in your city, please use duplicate copies of this questionnaire to enter information for each scheme.)

Priority Measures (PLEASE ANSWER 'YES' OR 'NO' AS APPROPRIATE)

11 Does the scheme which gives priority to Public Transport at signalised junctions also include :

Reserved Lanes/Tracks ?	Yes / No	111
Public Transport only Streets ?	Yes / No	112
Exclusive Right-of-Way ?	Yes / No	113
Public Transport only Turning Movements ?	Yes / No	114

12 What modes of transport does the scheme which gives priority at signalised junctions favour ?
(PLEASE TICK THE APPROPRIATE BOX)

Bus	Trolley Bus	Tram	LRT	Metro
121	122	123	124	125

Traffic Signal System

13 What is the type of signal system giving priority to Public Transport ?
(PLEASE TICK THE APPROPRIATE BOX)

Isolated Signal	Fixed Time UTC	On-Line UTC System e.g. SCOOT /SCATS	Other (Please Specify)
131	132	133	134

4 How many traffic signal junctions provide priority to Public Transport in the scheme ?
(PLEASE ENTER NUMBER IN BOX)

15 Is the Public Transport signal priority system linked to any other facilities such as Passenger Information System, Route Planning etc ? **Yes / No**
If 'Yes', please specify which facilities.

_____

_____

Vehicle / Signal Interface (PLEASE ANSWER 'YES' OR 'NO' AS APPROPRIATE)

16 What type of vehicle detection/location device is used in giving priority to Public Transport at signalised junctions for this scheme ?
(PLEASE TICK THE APPROPRIATE BOX)

Inductive Loops in reserved lanes	Inductive Loops (vehicle profile)	Inductive Loop and on-board vehicle transponder	Roadside Microwave Beacons	Radio Link	Infra-Red Beacon
161	162	163	164	165	166

17 Does the vehicle detection/location device communicate with the :
(PLEASE TICK THE APPROPRIATE BOX)

Local junction signal controller	Central signal control centre	Other (Please specify) _____
171	172	173

Impact of Priority at Signalised Junctions (PLEASE DELETE AS APPROPRIATE)

18 Has a Feasibility Study been undertaken? **Yes / No**

19 Have any 'Before and After' Studies to establish the effects of the scheme on vehicle delay been undertaken? **Yes / No**

20 Have any other 'Before and After' Studies been undertaken ? **Yes / No**
(IF 'YES' PLEASE SPECIFY WHICH EFFECTS WERE MEASURED ?) _____

_____

21 Are the results of any 'Before and After' studies available? **Yes / No**

22 Have the effects of priority at signalised junctions on Public Transport and traffic in general been estimated using a traffic model? **Yes / No**

23 Are the results of any traffic modelling available? **Yes / No**

Comments

Please use the remaining space to provide us with a short description of the scheme and your assessment of of its success , and your views on the scheme in general.

Thank You

January 1993

APPENDIX A-4

DEFINITION OF TRAFFIC SIGNAL SYSTEMS

APPENDIX A-4

DEFINITION OF TRAFFIC SIGNAL SYSTEMS

An isolated traffic signal installation is one where the control is purely by a local controller sited at the junction. The controller is not connected via telephone line or direct cabling to an urban traffic control system which may affect/alter timings. Similarly, the controller is not connected to other junction controllers directly or indirectly in a 'Master' 'Slave' format that will affect timings.

An isolated junction may form part of a cableless linking system where a number of junctions are kept in step by synchronisation of time clocks.

An isolated junction may be connected to a central computer purely for monitoring purposes.

An isolated junction controller is generally connected to vehicle detectors which demand and extend the green time on individual approaches to the junction. This facility is known as Vehicle Actuation (VA).

A Fixed-Time Urban Traffic Control System (UTC) is a central computer system that is linked to a number of traffic signal installations and pelican crossings (usually be telephone line). The UTC system has inbuilt in it a series of timing plans, modelled from historical traffic flow data, that are introduced by timetable or manual intervention into the junction controllers. A UTC system is used to provide linking of signalled junctions within an urban area to provide green time at these junctions that will assist progression and minimize overall delay. A UTC system cannot override the safety timings set on an individual junction controller.

Vehicle Actuation is utilized in UTC Systems to demand stages in the method of control of individual junctions that have been designated as "demand dependent".

Training plans can be incorporated into UTC systems to provide 'Green Waves' on demand which give given signals on predetermined routes for a specified time to clear the path for emergency vehicles.

A Traffic Adaptive urban traffic control system such as SCOOT is an enhanced fixed time system which uses 'fixed' plan timing as a basis for the timings on the individual junction controllers. This data is continually enhanced by analysis and modelling of real time information collected by on-street vehicle detectors to provide the most appropriate signal timings to handle the traffic flows in an urban area at that particular time.

APPENDIX A-5

QUEUE RELOCATION AND BUS PRE-SIGNAL TECHNIQUES LONDON, ENGLAND

MAIN ROAD QUEUE RELOCATION
vp:qrelocat.chp

NOTES

Signals re-timed at junction B to relocate queue from junction A to junction B; conditions eased in section B-A for buses.

KEY

signal junction

traffic queue

new bus lane

b bus

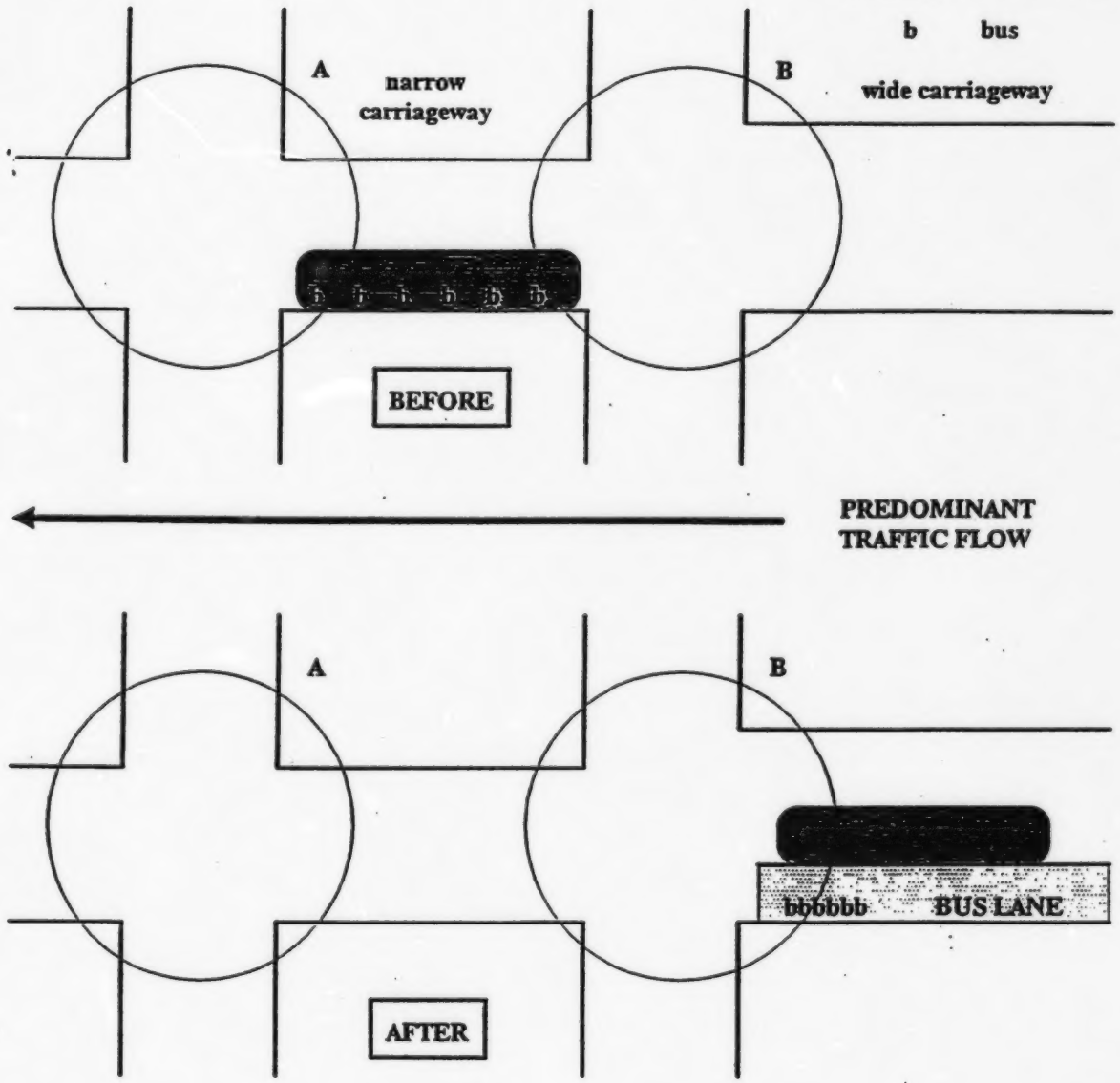


DIAGRAM 1

OPPOSING PHASE QUEUE RELOCATION
vp:opphqrel.chp

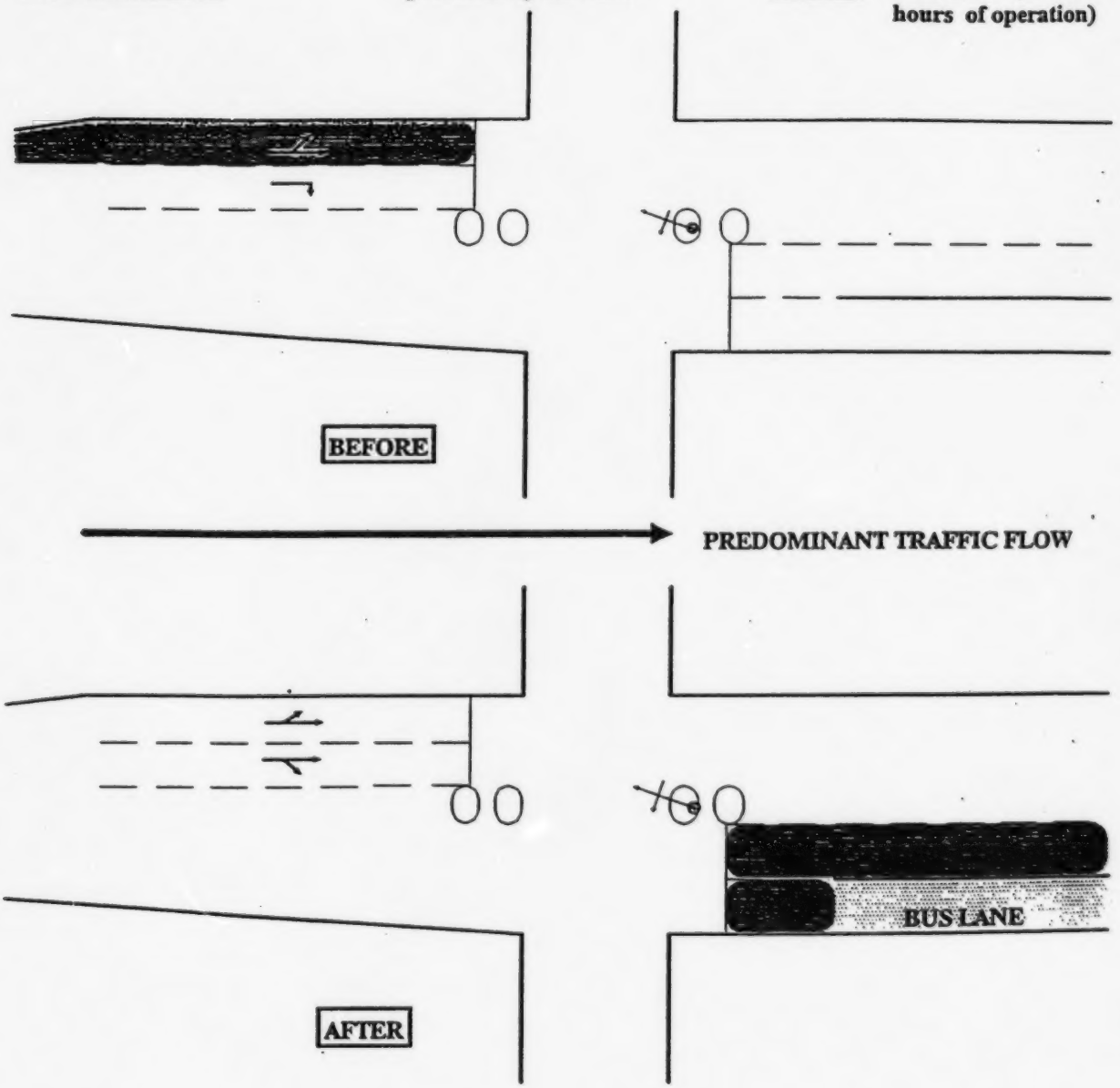
NOTES

Increase phase A and B green time and decrease phase C green time to increase A and B approach capacities. Queue relocated to phase C approach, with buses protected by bus lane

KEY

traffic queue

bus lane (revised hours of operation)



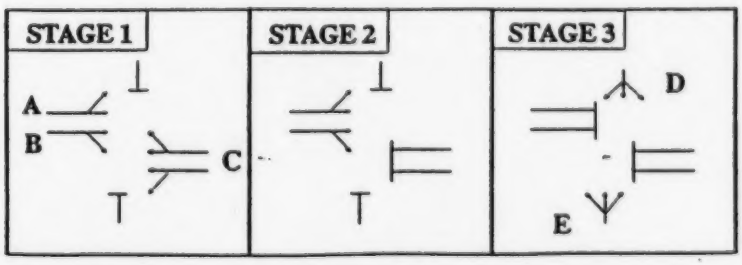
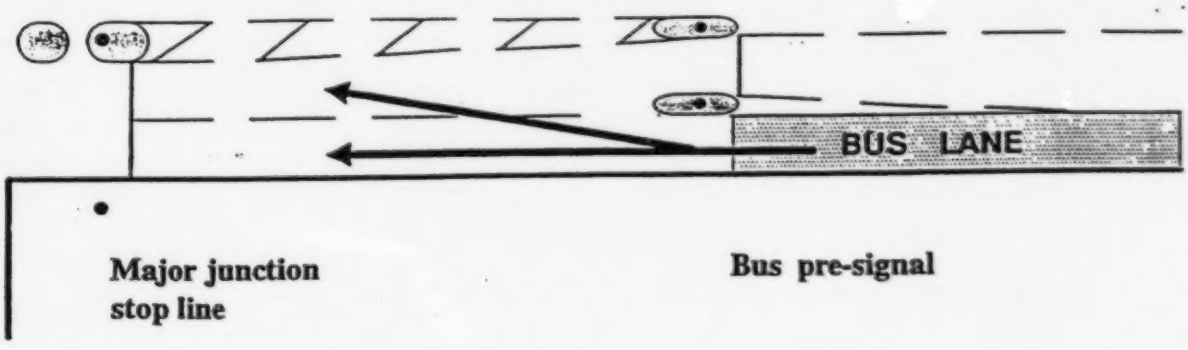


DIAGRAM 2

BUS PRE-SIGNALS

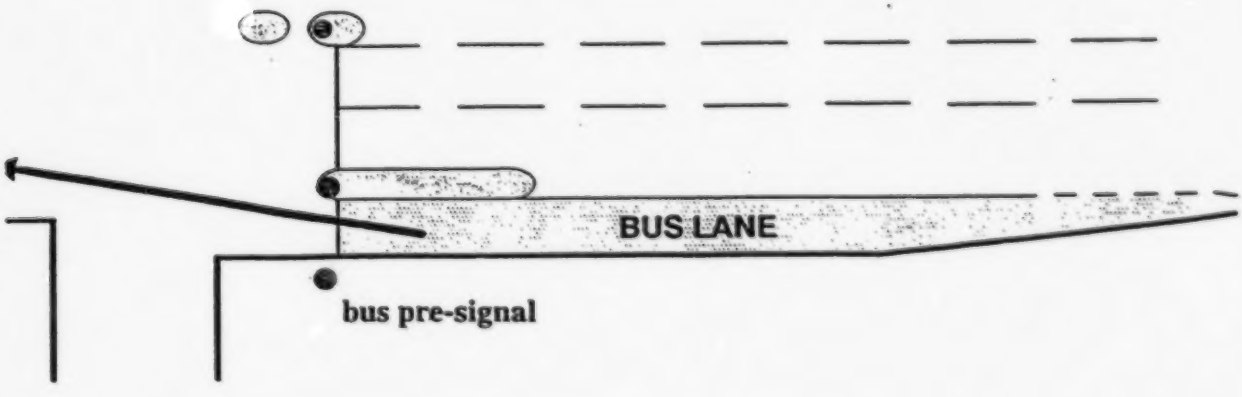
a) Bus pre-signal - positioned at the end of the bus lane, enabling buses to be at the front of the queue at the signal stop line



Major junction stop line

Bus pre-signal

b) Bus pre-signal with local widening - positioned at the major junction, enabling buses to obtain the green signal in advance of other traffic



bus pre-signal

DIAGRAM 3